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Utilization of

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# **Mining and Industrial Waste**

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October 13, 1977

**Ontario Room**

Macdonald Block, 2nd Floor  
Bay Street at Wellesley Street  
Toronto, Ontario



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Ministry of  
Industry and  
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MINING AND INDUSTRIAL WASTE  
SEMINAR  
October 13, 1977  
TORONTO

Sponsored by:

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UTILIZATION OF MINING AND INDUSTRIAL WASTE

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UTILIZATION OF MINING AND INDUSTRIAL WASTE

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OPENING REMARKS BY PETER YORK  
ASSISTANT DEPUTY MINISTER  
MINISTRY OF INDUSTRY AND TOURISM  
TO THE UTILIZATION OF MINING AND  
INDUSTRIAL WASTE SEMINAR  
ONTARIO ROOM, MACDONALD BLOCK  
QUEEN'S PARK, TORONTO  
OCTOBER 13, 1977

Ladies and gentlemen, on behalf of the Ministry of Industry and Tourism I would like to welcome you to the seminar on the Utilization of Mining and Industrial Waste. Our appreciations are due to the federal Department of Energy, Mines and Resources, the Ontario Ministry of the Environment and the Department of Fisheries and Environment Canada for their assistance in organizing this seminar.

I'd like to extend an especially warm welcome to our distinguished guests from the United States and England. Your presence here today proves the international concern that has arisen over the better use of wastes and encourages me in believing a solution will be found. To make a point: Another seminar on the Use of Slags is being held today in Paris, France and Dr. John Emery of McMaster University, who is a speaker at this seminar, was asked to present his paper at the Paris meeting. I also hope you will have time after your working session to stay in Ontario and enjoy the beauty of the fall colours.

Most of you well know that the U.S. Bureau of Mines and the Illinois Institute of Technology Research Institute have been successfully conducting the waste utilization symposium for the last 10 years. Although this is the first such seminar in Canada, we have not been idle in dealing with the wastes in Ontario's mining and industry.

While recognizing and appreciating the importance and contribution natural resources and industry make to Ontario and Canada, we are also aware that, as in many activities of mankind, mining and

industry create waste of one kind or another. Waste usually results as a by-product of a process or as an impurity which is removed to obtain a pure product. Sometimes it is a measure of inefficiency of the process. Waste represents a costly disposal problem and an environmental nuisance. But, it also represents something else -- a potential resource.

Today's society realizes our natural resources are not unlimited -- we must utilize our resources more fully. Waste as a resource can no longer be merely discarded.

Today's seminar focuses on the problems of using waste and will highlight how some in industry and science have attempted to convert waste to useful products.

This seminar won't have the solutions to all your problems. But undoubtedly by knowing what other people have done and by asking questions you will be able to generate your own ideas for better use of materials now wasted. As you will learn during the discussions today, using wastes is not only ecologically wise it can also be economical.

Ladies. Gentlemen. Welcome to Ontario. I hope today will be both informative and profitable for all of you.

Thank you.



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## CANMET

Canada Centre  
for Mineral  
and Energy  
Technology      Centre canadien  
de la technologie  
des minéraux  
et de l'énergie

### MINERAL WASTE - ASSET OR LIABILITY?

R.K. COLLINGS

INDUSTRIAL MINERALS LABORATORY  
NON-METALLIC AND WASTE MINERALS SECTION

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MINERAL SCIENCES LABORATORIES  
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MINERAL WASTE - ASSET OR LIABILITY?

by

R.K. Collings\*

\* \* \*

ABSTRACT

The annual production of mineral and mineral-based wastes in Canada is conservatively estimated to be 400 million tons. Over 90 per cent of this amount is in the form of waste rock or mill tailings from the mining and mineral processing industry. The remainder is in the form of slags, ashes and sludges from the metallurgical and chemical industries. Because of impurity content, remote location, or both, most wastes have limited usefulness and, indeed, are a liability in that they must be transported to waste disposal sites. Furthermore such sites often must be revegetated to minimize possible contamination of groundwater, and rivers and lakes by runoff and seepage. Many mineral wastes do, however, have significant potential value. Some contain small percentages of metals that may be economically recoverable with price increases - others consist of mineral material that may be used for such purposes as construction aggregate, railroad ballast, and in the manufacture of bricks or blocks. Interest in such uses for mineral wastes has been increasing in the last few years. This paper reviews the types of mineral wastes available in Canada, lists and briefly describes a number that have potential value, and notes possible uses and related research by CANMET and other organizations.

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\* Head, Non-Metallic and Waste Minerals Section, Industrial Minerals Laboratory, CANMET.

## INTRODUCTION

The mineral wastes discussed in this paper are the solid mineral or mineral-based rejects from three specific segments of Canadian industry - mining and mineral processing, metallurgical, and chemical. Each segment generates substantial amounts of mineral wastes that must be trucked, railed, or piped to waste disposal areas. Scattered throughout Canada, these wastes collectively comprise billions of tons of semi-processed rock and mineral raw material. The current rate of production is conservatively estimated to be 400 million tons per year, enough to cover the entire area of metropolitan Toronto to a depth of 1 ft. If this same amount were to be piled around Toronto's CN Tower, the apex of the cone so formed would be only about 150 ft below the top of this 1800-ft structure.

Mineral waste piles are costly to maintain and, in some instances, may result in pollution of groundwater and nearby rivers and lakes. These factors, along with an increasing appreciation of the many potential applications for mineral wastes, have stimulated studies and research directed towards finding new uses. This present seminar is positive evidence of the current interest in mineral waste utilization.

## SOURCE AND VARIETY OF MINERAL WASTES

As noted in the introduction, only those solid mineral or mineral-based wastes from the mining and mineral processing,

metallurgical, and chemical industries will be discussed in this paper. These wastes, with the principal exception of waste rock from mines and slags from metallurgical operations, are normally in a finely divided state. Although they vary widely in mineral and chemical composition from location to location, material from any one plant normally would have relatively uniform physical and chemical characteristics. Many mineral wastes have limited value as sources of raw mineral material because of high impurity content, remote location, or both. However, some are favourably located and of interest because of contained metals and minerals or because of certain physical and chemical characteristics. Such wastes may be responsive to newly developed or improved beneficiation techniques for separating and recovering metals and minerals or they may be useful for a variety of purposes, e.g., as road fill and construction aggregate, as railroad ballast, as a mineral filler in asphaltic paving, plastics, and other products, in the manufacture of bricks, concrete blocks, and various types of thermal insulations, and as chemical raw material.

Because wastes from the three noted industrial sectors differ with respect to type, physical and chemical nature, and degree of utility, they will be considered separately in this paper.

#### MINING AND MINERAL PROCESSING WASTES

An estimated 375 million tons of mining and mineral processing wastes are produced annually in Canada. These wastes collectively

account for well over 90 per cent of the total mineral wastes produced. They are of several principal types - waste rock from open pits or from underground development work in mines, coarse mill rejects from screening or heavy media separation, and fine rejects or mill tailings from screening, magnetic separation, flotation, or other beneficiation process. Each type, principally because of physical nature but also because of chemical or mineralogical composition, would be useful for different applications.

Because the nature of mining and mineral processing wastes varies with the type of mine, these wastes and possible opportunities for use will be discussed on the basis of origin, e.g., base metal, iron ore, precious metal, and industrial mineral mines, and energy or energy-based mines, including uranium, coal, and tar sands. Fly ash from coal-fired thermal plants is also included in this latter group.

#### Base Metals

Base metals, e.g., copper, lead, zinc, nickel, are produced in all provinces with the exception of Alberta, Nova Scotia, and Prince Edward Island by surface or open-pit, and underground mining.

Waste rock from underground base metal mines is usually not produced in large quantities except during development work. This rock is left underground as backfill although it may be brought to the surface and used for road construction and maintenance. By contrast, millions of tons of waste rock often are produced by open pit mining operations. Such waste rock may find limited local use in road construction and as construction

aggregate; however, large tonnage uses are few because of the remote locations of many of the mines, e.g., Gaspé Copper Mines Limited at Murdochville in the Gaspé Peninsula, and Texasgulf Canada Limited at Kidd Creek in the Timmins area.

Production of mill tailings by base metal mines is also measured in millions of tons. Collectively these tailings are finely ground and contain relatively large amounts of metallic sulphides, chiefly pyrite and pyrrhotite. Their impure nature and remote location limit use to local applications, e.g., as mine backfill, in road maintenance and, occasionally, as smelter flux. Some tailings may contain small but significant amounts of metals and minerals that could perhaps be profitably recovered at a future date should metal or mineral prices increase. Mill tailings from a copper-zinc-lead mine at Buchans, Newfoundland, are of more immediate interest. These tailings contain up to 30 per cent or more than 0.5 million tons of barite which is potentially recoverable for use as a weighting agent in off-shore drilling for oil. Studies by CANMET have demonstrated the technical feasibility of such recovery<sup>(1)</sup>. Barite is currently recovered from mill tailings at two other locations - from lead-zinc tailings near Spillimacheen, and from base metal mine tailings near Invermere, in southeastern British Columbia. Also of interest are tailings from the open pit, lead-zinc-copper-silver mine operated by Brunswick Mining and Smelting Corporation at Bathurst, New Brunswick. These tailings contain up to 35 per cent of the metal values present in the original ore. Studies to improve metal recovery are in progress by the company. CANMET is also investigating techniques for improving metal recovery from finely divided sulphide ores and

tailings such as those at Bathurst. The pyrite and pyrrhotite present in most base metal tailings could also be separated and processed to recover iron, nickel, and sulphur should markets for these metals or minerals favour such recovery. In the meanwhile, some tailing dumps are being revegetated or reclaimed and used as public parks or as wild life areas.

#### Iron Ore

Iron ore is produced in four provinces - Newfoundland (Labrador), Quebec, Ontario, and British Columbia. Mining is largely by open pit, the chief exception being the underground mine at Wawa, Ontario.

Open pit iron mines produce large amounts of waste rock and whereas the bulk is sent to rock dumps, minor quantities are used locally in road construction, as crushed stone and construction aggregate and, occasionally, as railroad ballast. Granitic waste rock from the Hilton mine at Shawville, Quebec, for example, has been used as aggregate and also as railroad ballast, and a portion of the trap rock from the open pit at Marmora, Ontario, is used as aggregate in asphaltic mixes. Waste rock from each of these locations is being studied at CANMET for suitability as aggregate in concrete.

Iron ore mining and processing operations generate large quantities of mill tailings which usually are conveyed to tailings disposal areas. Mill tailings from several iron mines in north-eastern Quebec and Labrador contain 10 per cent or more of hematite and studies are in progress by at least one operator to determine the feasibility of recovering this iron. Feldspar tailings from

the processing plant operated by Quebec Iron and Titanium Corporation at Tracy, Quebec, are being processed at Longueuil for use as roofing granules. Minor but significant quantities of iron ore tailings are used at other locations as fine aggregate in concrete and in road construction and maintenance. Other uses also are being studied. For example, interest has been shown in the possibility of producing building brick from iron ore tailings and CANMET researchers have demonstrated the technical feasibility of producing a dry-pressed, facing brick with tailings from the Hilton mine<sup>(2)</sup>. An economic appraisal of this process has also been made<sup>(3)</sup>.

#### Precious Metals

Approximately 75 per cent of Canada's gold production is derived from underground mines; the remainder, along with most of the silver production, is principally recovered from base metal ores.

Waste rock from underground gold and silver mines normally is not produced in large amounts. Where produced it is usually used underground as backfill although it may be brought to the surface and used in road construction and maintenance.

Mill tailings production at gold and silver mines, by contrast, is usually large. Mill tailings may be used as backfill but they normally are sluiced to tailing disposal areas where they may be revegetated to reduce dusting, erosion, and possible surface or ground water contamination. Some tailings contain traces of gold and silver that may be economically recovered with

price increases. Gold-silver tailings are finely ground and usually contain relatively large percentages of quartz and feldspar with only minor amounts of metallic sulphides, e.g., pyrite and pyrrhotite. These tailings could be of interest for building products manufacture, e.g., sand-lime brick and autoclave concrete block, if research indicates technical feasibility and if local markets are large enough to justify establishing manufacturing facilities. Preliminary research at CANMET on the feasibility of using gold mine tailings for sand-lime and dry-pressed brick manufacture has produced inconclusive results to date, however, additional studies are planned<sup>(4)</sup>.

#### Industrial Minerals

Industrial minerals are produced in all provinces of Canada without exception. In contrast to metal mines, most industrial or non-metallic mining operations do not generate significant tonnages of waste rock or mill tailings. There are, of course, exceptions, notably asbestos operations in Newfoundland, Quebec, Ontario, and British Columbia, and potash mines in Saskatchewan.

Large quantities of waste rock are produced by open pit asbestos operations but little use is made of this material. The bulk is stockpiled in large dumps with only minor tonnages being used locally as roadfill or as mine backfill.

Asbestos tailings also are produced in large amounts and are of interest for the recovery of additional metals and mineral material. Asbestos tailings contain 5 to 10 per cent of short fibre along with significant amounts of magnesium (40% MgO), nickel (0.25%), chromium (0.5%), and iron (6 to 8%). Studies

have been made on the recovery of the short fibre by wet processing methods, and some work has been undertaken to recover magnesium, nickel, iron, and chromium<sup>(5,6)</sup>. Studies by CANMET have demonstrated the technical feasibility of producing mineral wool from these tailings as well as a nickel-iron co-product<sup>(7)</sup>.

In Saskatchewan, approximately 10 million tons of waste salt are produced annually during potash mining operations. Limited quantities are used for snow and ice control on highways but the bulk is stockpiled on surface. Salt brine from a potash solution mine at Belle Plaine is recovered and used for the production of fine evaporator salt.

Also of interest are tailings from the nepheline syenite operations north of Peterborough, Ontario. These tailings can be reprocessed through high intensity magnetic separators to yield a 40 to 50 per cent recovery of glass grade nepheline syenite. The trap rock fines from a roofing granule plant at Havelock, Ontario, have potential value as filler material in asphalt and possibly in rubber and plastics. Two non-metallic mineral tailings of interest in southeastern Quebec are the calcite tailings from the columbium oxide plant, now closed, at Oka and tailings from the magnesite-dolomite operation at Kilmarnock. The former has been studied as a soil additive and as a neutralizer for acid soils that are common in the southwestern portion of that province, whereas the latter may be suitable as a refractory raw material.

#### Energy Minerals

Mineral wastes from three "energy mineral" mining and mineral processing operations, uranium, coal, and tar sands, are

discussed in this section. Fly ash from coal-fired power plants, although not associated with mining or mineral processing operations, has been included because of its close relationship to coal.

Over 80 per cent of the total production of uranium in Canada is derived from two underground mines at Elliot Lake, Ontario. The remainder is from northern Saskatchewan, also with two mines, one underground and one open pit. Large quantities of mill tailings are produced annually, especially in Ontario. Tailings from the Ontario mines are finely divided and consist essentially of quartz with minor pyrite, uranium, radium and thorium. Interest in the possibility of using these tailings for glass manufacture has been expressed by at least one glass manufacturer; however, the possible radiological hazard has effectively discouraged such use. Research aimed at reducing the radioactive minerals in these tailings is in progress in CANMET. Successful completion of these studies could result in renewed interest in developing uses for uranium tailings.

An estimated 7 million tons of coal shale rejects from washing plants are produced annually in Canada's five coal-producing provinces - Nova Scotia, New Brunswick, Saskatchewan, Alberta and British Columbia. These wastes have few current applications and are usually sent to tailings disposal areas. However, some waste embankments contain up to 35 per cent of coal that could be recoverable, in part, through use of improved beneficiation techniques. These rejects also contain 20 to 30 per cent alumina and are of interest as a source of alumina to supplement or replace imported bauxite in aluminum manufacture. Recovery of alumina

from coal shales is being studied at CANMET.

Production of tailings from tar sand operations in Alberta will be in the order of 100 million tons annually when the output from a plant under construction by Syncrude Canada Limited, scheduled for completion in 1978, is added to that of the current operator, Great Canadian Oil Sands Limited. Centrifuge tailings produced at one stage in the processing of tar sands contain 8 per cent titanium and 4 per cent zirconium. For a plant rated at 125,000 barrels of oil per day, these tailings would yield 104,000 tons of titanium minerals and 45,000 tons of zircon annually, assuming 75 per cent recovery<sup>(8)</sup>. Research by Syncrude Canada Limited has demonstrated the technical feasibility of recovering these minerals along with metallic iron<sup>(9)</sup>. The recovery of vanadium and nickel from fly ash resulting from the extraction of petroleum from the bitumen portion of the tar sands has also been studied<sup>(10)</sup>.

A recent survey by CANMET showed there were approximately 2 million tons of fly ash produced by the 21 major coal-fired thermal power plants in Canada in 1975-76<sup>(11)</sup>. About 5 per cent of this amount was sold, principally for use as an additive or partial replacement of portland cement in concrete, the remainder was sent to waste disposal sites. Although the major current use of fly ash is as an additive to concrete, it is not expected that such usage will exceed 10 per cent of the production of cement in any regional market. Other uses will be required to absorb the remainder. Potential uses include the manufacture of lightweight aggregate and as a soil cement in highway construction<sup>(11)</sup>.

## METALLURGICAL INDUSTRY WASTES

The metallurgical industry of Canada produces a variety of mineral-based wastes that, in total, amount to about 15 million tons annually. Chief among these are blast and steel furnace slags and slags from non-ferrous smelting and refining operations. Other mineral or mineral-based wastes are produced in smaller amounts and include flue and foundry dusts, foundry sand, bottom ash, etc. Many wastes in this latter group have specific reuse applications, e.g., flue dust may be pelletized and reused in the furnace, and spent foundry sands are being recovered for reuse. Because such wastes vary widely in physical and chemical composition as well as in potential applications, no attempt will be made to review them here. The remainder of this section will be devoted to brief discussions of blast furnace, steel, and non-ferrous slags.

### Blast Furnace Slag

Blast furnace slag is produced during the manufacture of pig iron at three principal locations in Canada - Sydney, Nova Scotia, and Sault Ste. Marie, and Hamilton (two plants), Ontario. Blast furnace slag is principally composed of lime, alumina, and silica. Production is in the order of 2.5 million tons per year, 70 per cent of which is used as road base in highway construction, in mineral wool and lightweight aggregate manufacture, as railroad ballast, and as land fill. New and improved uses for this material are being studied by a number of producers and other interested groups. A research program at McMaster University in Hamilton, for example,

is aimed at producing a granulated or pelletized slag for use as road base and as an aggregate and partial replacement for portland cement in autoclave concrete block manufacture<sup>(12)</sup>. Studies related to the production of mineral wool insulation from blast furnace slag are being carried out by CANMET.

#### Steel Slag

Steel slag is produced by steel plants at 40 to 50 locations in Canada but total annual production probably does not exceed 2 million tons. The composition of steel slags is highly variable, but they essentially are composed of calcium silicates, calcium and ferrous oxides, and free lime. Approximately 75 per cent of the total steel slag produced is recycled to the blast furnace at locations having integrated iron and steel facilities but few other uses have been developed in Canada. Steel slag tends to be dimensionally unstable because of contained lime and magnesia which result in expansion on hydration. Such expansion can be controlled or nullified by acid treatment or by aging. Steel slag is used in a number of countries, including the United States, in highway base and shoulder construction, as a base or fill material for paved parking lots, as railroad ballast, and as aggregate in bituminous mixes. It has been reported that steel slag-bituminous mixes used in highway surfacing have resulted in excellent skid and stripping resistance<sup>(12)</sup>.

#### Non-Ferrous Slags

A third and major source of slag in Canada is the non-ferrous smelters. Annual production is estimated to be 8 million tons

and is mostly from copper, nickel, zinc, or lead smelters at Murdochville and Noranda, Quebec, Sudbury, Falconbridge, and Timmins, Ontario, Flin Flon and Thompson, Manitoba, and Trail, British Columbia. This slag is normally disposed of as landfill although nickel slag from the Sudbury area has been used for over 25 years as railroad ballast material. Copper slag from the Noranda and Flin Flon smelters has also been used for this purpose<sup>(13)</sup>. Dicalcium silicate slag resulting from the production of magnesium metal by the Pigeon process at Haley Station, Ontario, has been studied as raw material for building products manufacture. Good quality building brick was produced by an autoclave process developed at CANMET<sup>(14)</sup>.

#### CHEMICAL INDUSTRY WASTES

A wide variety of mineral or mineral-based wastes are produced during the manufacture of industrial chemicals in Canada. Production is in the order of 7 to 8 million tons annually. Many chemical wastes have limited use potential because of the small quantities available or their complex nature, which makes recovery of any one mineral component both difficult and costly. However, there are exceptions, for example red mud, produced during the manufacture of alumina by the Bayer process, and several varieties of chemical gypsum, including phosphogypsum from phosphate fertilizer plants, fluorogypsum from hydrofluoric acid manufacture, and sulfogypsum which will be produced in Quebec in the early 1980's by titanium dioxide pigment producers. There

is a continuing, high level of interest in the development of new uses for these wastes - red mud for a variety of applications, and chemical gypsum for gypsum products manufacture and as an additive to portland cement. These materials and possible applications are discussed in the following sections.

Red Mud

Red mud is a waste product that is formed during the digestion of bauxite in sodium hydroxide in the Bayer process for the manufacture of aluminum metal. It is produced in Canada at one location only, Arvida, Quebec, at an estimated rate of 1.5 million tons per year. This material is very finely divided and somewhat variable in composition depending, to a large degree, on the source and mineral nature of the bauxite from which it is formed. Red mud has been the subject of much research in Canada and in many other countries, notably Japan, West Germany, Jamaica, and the United States. This research has been directed not only towards the recovery of contained minerals and metals but also towards the utilization of the red mud itself in certain applications. The technical feasibility of the recovery of iron powder, titanium dioxide, and aluminum sulphate, has been demonstrated and further development work is in progress by several of the leading manufacturers of aluminum<sup>(15)</sup>. The estimated 1.5 million tons of red mud produced annually in Canada would yield 300,000 tons of alumina, 180,000 tons of iron oxide, 100,000 tons of titanium dioxide, and 140,000 tons of soda<sup>(16)</sup>. Other potential applications that have

been studied include use of red mud as a substitute, or partial replacement, for fluorspar in steel and metal alloy manufacture, as an additive material in clay brick manufacture, as a mineral pigment, as a flocculating agent in water purification, and as a pelletizing agent for iron ore<sup>(15,17)</sup>.

#### Phosphogypsum

Phosphogypsum is a waste product from the manufacture of phosphoric acid for use in phosphate fertilizer manufacture. It is produced at 12 plants in Canada, 4 in Alberta, 3 in British Columbia, 2 in both Ontario and Quebec, and 1 in New Brunswick. Canadian production is about 4 million tons annually. Phosphogypsum is of interest as a source of raw material for gypsum products manufacture, especially in areas where natural gypsum deposits are distant from gypsum product plants, e.g., in Alberta and Quebec, or of low purity. Phosphogypsum, although impure, can be upgraded for use in gypsum products by relatively simple mineral processing techniques<sup>(18)</sup>. Unfortunately phosphogypsum contains small quantities of radium that could represent a radiological hazard if this material were to be used in gypsum products. The radium content, depending on the source of the raw phosphate rock, may vary from 10 to 50 or more picocuries per gram. That produced in Canada ranges from 25 to perhaps 40 picocuries per gram. However, there appears to be no consensus of opinion among specialists as to the degree of hazard represented by this radium. Many feel that 20 to 25 picocuries in gypsum products constitute no potential hazard whereas others have stated that a concentration of 10 picocuries per gram is excessive<sup>(19)</sup>. In

any event, this controversy over the relative degree of hazard of radium in phosphogypsum is effectively discouraging utilization of this material by the gypsum products industry of Canada. Phosphogypsum is used in other countries including Japan and Germany for gypsum products. Research directed towards reducing the radium content of phosphogypsum to a more acceptable level is needed if the full potential of this material is to be realized.

#### Fluorogypsum

Fluorogypsum is produced by the action of sulphuric acid on finely ground fluorspar during hydrofluoric acid manufacture. Production from two plants in Ontario and one in Quebec is about 500,000 tons per year. This material is finely divided and relatively impure; however, it is of interest as a source of gypsum for gypsum products manufacture and as a set-control agent in portland cement. Studies of the beneficiation and evaluation of fluorogypsum for gypsum products manufacture are in progress at CANMET, and research by others has demonstrated the technical feasibility of utilizing this material as a replacement for natural gypsum or anhydrite in portland cement<sup>(20)</sup>.

#### Sulfogypsum

Production of sulfogypsum in Canada is expected in the early 1980's when the two Quebec-based titanium dioxide pigment plants, at Varennes and Tracy, install facilities for neutralizing a spent sulphuric acid plant effluent. The rate of production is expected to be 300,000 tons per year. Pilot plants are in operation at both locations to study this problem and its solution. Ground limestone is used as the neutralizing agent. The resulting

sulfogypsum is finely crystallized and of high purity. Interest in this product has been expressed by several gypsum product producers and also by one or two cement companies. Preliminary work undertaken at CANMET shows that this material requires little beneficiation to render it satisfactory for use in gypsum products.

#### CONCLUDING REMARKS

The bulk of the mineral and mineral-based wastes discussed in this paper must be considered a liability because most wastes will not only never be used but they also must be contained in tailing ponds or waste dumps and perhaps revegetated. Despite this, many of Canada's mineral wastes are of value as alternate or supplemental sources of mineral raw material. Interest in such wastes is growing and will continue to grow as the higher grade and more readily accessible mineral deposits are mined to depletion or, as in some urban centres, are restricted from mining by local regulations.

The successful application of mineral wastes to particular end-uses cannot be accomplished without extensive laboratory research and process development, but the quantity and variety of raw material available and the diversity of possible end-use applications together present a challenge that should not go unheeded by industry and government, especially in view of developing shortages in raw mineral resources, particularly construction materials, in certain urban centres. Increased utilization of mineral wastes

will have three beneficial effects - conservation of native, non-renewable mineral resources, conservation of energy in that many wastes are partially processed and finely ground, and reduction or elimination of pollution or potential pollution from waste dumps - all three of benefit to Canada and its people.

Although interest in mineral waste is growing, this interest is tempered by the fact that there is little published information on the basic nature of these wastes, their availability, and potential utility. Several trade journals now carry Waste Exchange columns and various organizations, for example Environment Canada and Energy, Mines and Resources, are trying to fill this information gap. Environment Canada is in the process of establishing a Waste Exchange Information Service that will allow industry to not only record information on the nature and availability of industrial wastes but also on specific material requirements that could, perhaps, be met by industrial wastes<sup>(21)</sup>. CANMET formally initiated a program of collecting, compiling, and evaluating mineral waste data and samples in 1975. A report on Mining Wastes in Ontario was published in 1976<sup>(22)</sup>. A similar report on Mining Wastes in Quebec is in press and will be available early next year<sup>(23)</sup>. Work on mining wastes in British Columbia has been started and the completed report will be available late in 1978. Reports on mining wastes in the Atlantic and Prairie Provinces are scheduled for 1979. Metallurgical wastes will be covered by a separate report which will be available in the latter part of 1978. Preliminary reports on chemical wastes in Canada have been prepared but these will not be available in

published form until 1980.

The author would be pleased to receive additional information on mineral wastes from the three industrial sectors discussed in this paper, particularly with regard to unique opportunities for increased utilization.

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MINERAL AND MINERAL-BASED WASTE PRODUCTION (CANADA)

<u>MINING AND MINERAL PROCESSING</u>	<u>MILLION TONS/YEAR</u>
BASE METALS	100
IRON ORE	80
GOLD AND SILVER	4-5
INDUSTRIAL MINERALS	5-10
ASBESTOS	50-60
POTASH	10
ENERGY MINERALS	
URANIUM	4-5
COAL	7
TAR SANDS	35-100
FLY ASH (ENERGY RELATED)	2
<u>METALLURGICAL INDUSTRY</u>	
BLAST FURNACE SLAG	.5
STEEL SLAG	.5
NON-FERROUS SLAG	8
<u>CHEMICAL INDUSTRY</u>	
PHOSPHOGYPSUM	4
FLUOROGYPSUM	1
SULFOGYPSUM	0.3
RED MUD	1.5
TOTAL	400±

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\* INVESTIGATED BY CANMET

\*\* UNDER INVESTIGATION BY CANMET

TYPE - IRON ORE - WASTE ROCK AND MILL TAILINGS

AMOUNT - 80 MILLION TPY (NFLD., QUE., ONT., B.C.)

COMMENT - REMOTE LOCATION, MOST MINES, LIMITS USE - SOME MINES  
MORE FAVOURABLY LOCATED (SHAWVILLE, QUE., MARMORA, ONT.)

USE - ROCK - ROAD CONSTRUCTION - RAILROAD BALLAST - CONCRETE AGGREGATE\*.  
- TAILINGS - FINE AGGREGATE - ROOFING GRANULES  
- MANUFACTURE OF BRICKS\* AND BLOCKS  
- RECOVERY OF IRON VALUES (10% AT SOME MINES)\*\*

\* INVESTIGATED BY CANMET

\*\* UNDER INVESTIGATION BY OTHERS

TYPE

- GOLD AND SILVER - WASTE ROCK AND MILL TAILINGS

AMOUNT

- 4 TO 5 MILLION TPY (QUE., ONT.)

COMMENT

- LIMITED PRODUCTION OF ROCK - TAILINGS USUALLY ARE HIGH-QUARTZ,  
LOW-METALLIC SULPHIDES - LIMITED USE

USE

- ROCK - MINE BACKFILL - ROAD CONSTRUCTION - RAILROAD BALLAST

- TAILINGS

- BACKFILL  
- RECOVERY OF GOLD-SILVER VALUES  
- LOCAL PRODUCTION OF SAND-LIME BRICK\*

\* PRELIMINARY STUDY BY CANMET

TYPE - INDUSTRIAL MINERALS - EXCLUDING ASBESTOS AND POTASH

AMOUNT - 5 TO 10 MILLION TPY (ALL PROVINCES)

COMMENT - LIMITED PRODUCTION OF WASTE ROCK AND TAILINGS AT MOST MINES - LIMITED USE

USE - TAILINGS - NEPHELINE SYENITE, PETERBOROUGH, ONT., - FURTHER  
PROCESSING TO RECOVER GLASS-GRADE NEPHELINE SYENITE\*  
- TRAP ROCK, HAVELOCK, ONT., - FILLER MINERAL IN  
ASPHALTIC MIXES, RUBBER, PLASTICS, MINERAL-WOOL  
MANUFACTURE (POTENTIAL USE)  
- CALCITE, OKA, QUE., - SOIL NEUTRALIZER FOR ACID SOILS, \*\*  
NEUTRALIZER FOR ACID PLANT EFFLUENTS (POTENTIAL USE)

\* INVESTIGATED BY CANMET

\*\* INVESTIGATED BY AGRICULTURE CANADA

TYPE - ASBESTOS - WASTE ROCK AND MILL TAILINGS

AMOUNT - 50 TO 60 MILLION TPY (QUE., B.C., ONT.)

COMMENT - CONCERN OVER POTENTIAL HEALTH HAZARD OF ASBESTOS FIBRE MAY DISCOURAGE USE

USE - ROCK - LIMITED APPLICATION IN ROAD CONSTRUCTION AND MINE BACKFILL

- TAILINGS - RECOVERY OF CONTAINED MINERAL AND METAL VALUES INCLUDING  
SHORT FIBRE (5 TO 10%), MAGNESIUM, NICKEL, CHROMIUM, IRON \* 35  
- PRODUCTION OF MINERAL WOOL INSULATION\*

\* INVESTIGATED BY CANMET

TYPE - ROCK SALT AND BRINE FROM POTASH MINING

AMOUNT - 10 MILLION TPY (SASK.)

COMMENT - 2 TO 3 TONS OF SALT ARE PRODUCED FOR EACH TON OF POTASH -  
MOSTLY STOCKPILED ON SURFACE - LIMITED CURRENT USE

USE - ROCK SALT - MINOR QUANTITIES USED ON HIGHWAYS FOR SNOW AND ICE CONTROL .

- BRINE - BRINE FROM SOLUTION MINE AT BELLE PLAINE USED FOR PRODUCTION  
OF FINE EVAPORATOR SALT

TYPE

- URANIUM - WASTE ROCK AND MILL TAILINGS

AMOUNT

- 4 TO 5 MILLION TPY (0NT., SASK.)

COMMENT

- MINOR WASTE ROCK PRODUCTION,  
RADIOACTIVE MINERALS IN TAILINGS COULD DISCOURAGE USE

USE

- RECOVERY OF THORIUM AND RARE EARTH MINERALS (POTENTIAL USE)  
- SOURCE OF GLASS SAND IF RADIOACTIVE CONTAMINENTS REMOVED\*

\* UNDER INVESTIGATION BY CANMET

TYPE

- COAL - WASH PLANT REJECTS

AMOUNT

- 7 MILLION TPY (N.S., N.B., SASK., ALTA., B.C.)

COMMENT

- REJECTS PRINCIPALLY CLAY AND SHALE BUT WITH SIGNIFICANT AMOUNT  
OF COAL (35% +)

USE

- RECOVERY OF COAL\*  
- LIGHTWEIGHT AGGREGATE MANUFACTURE (POTENTIAL USE)  
- RECOVERY OF ALUMINA FOR ALUMINUM MANUFACTURE\*\*

\* UNDER INVESTIGATION

\*\* UNDER INVESTIGATION BY CANMET

TYPE

- TAR SANDS - SAND TAILINGS

AMOUNT

- 35 TO 100 MILLION TPY (ALTA.)

COMMENT

- TAILINGS CONTAIN SIGNIFICANT AMOUNTS OF TITANIUM AND ZIRCONIUM

USE

- RECOVERY OF TITANIUM AND ZIRCONIUM FROM TAILINGS\*

- RECOVERY OF VANADIUM AND NICKEL FROM BITUMEN FLY ASH\*\*

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\* UNDER INVESTIGATION BY SYNCRUE CANADA

\*\* INVESTIGATED BY CANMET

TYPE

- FLY ASH FROM COAL-FIRED POWER PLANTS

AMOUNT

- 2 MILLION TPY (N.S., N.B., ONT., MAN., SASK., ALTA.)

COMMENT

- FLY ASH MAY BE USED AS PARTIAL REPLACEMENT FOR PORTLAND  
CEMENT IN CONCRETE

USE

- 100,000 TPY NOW USED IN CONCRETE\*  
- MANUFACTURE OF LIGHTWEIGHT AGGREGATE (POTENTIAL USE)  
- SOIL CONDITIONER (POTENTIAL USE)

\* UNDER INVESTIGATION BY CANMET

TYPE

- BLAST FURNACE SLAG

AMOUNT

- .5 MILLION TPY (WASTE) (N.S., ONT.)

COMMENT

- PRINCIPAL CONSTITUENTS ARE LIME, ALUMINA, AND SILICA

USE

- ROAD BASE, IN LIGHTWEIGHT AGGREGATE AND MINERAL WOOL MANUFACTURE,  
AND AS RAILROAD BALLAST  
- GRANULATED SLAG BEING EVALUATED AS ROAD BASE MATERIAL,  
AS CONCRETE AGGREGATE, AND AS A CEMENTITIOUS BINDER\*  
- LIQUID SLAG FOR MINERAL WOOL MANUFACTURING\*\*

\* UNDER INVESTIGATION BY McMaster University

\*\* UNDER STUDY BY CANMET

TYPE - STEEL SLAG

AMOUNT - 0.5 MILLION TPY (WASTE) (N.S., QUE., ONT., MAN., SASK., ALTA., B.C.)

COMMENT - COMPOSITION VARIABLE, PRINCIPALLY CALCIUM SILICATES, CALCIUM AND FERROUS OXIDES, FREE LIME, - UNSTABLE - BULK OF STEEL SLAG IS RECYCLED TO BLAST FURNACE

USE - LIMITED APPLICATIONS IN CANADA - IN U.S. AND OTHER COUNTRIES USED IN HIGHWAY BASE AND SHOULDER CONSTRUCTION, AS FILL AND BASE FOR PARKING LOTS, AS RAILROAD BALLAST, AS AGGREGATE IN BITUMINOUS MIXES, ETC. - SIMILAR APPLICATIONS SHOULD BE RESEARCHED IN CANADA.

TYPE - NON-FERROUS SLAG

AMOUNT - 8 MILLION TPY (N.B., QUE., ONT., MAN., B.C.)

COMMENT - COMPOSITION VARIABLE BUT PRINCIPALLY IRON, LIME, SILICA-LIMITED USE

USES - RAILROAD BALLAST (SUDBURY, ONT., NORANDA, QUE.)  
- BUILDING BRICK PRODUCTION\*

\* INVESTIGATED BY CANMET

TYPE - PHOSPHOGYPSUM

AMOUNT - 4 MILLION TPY (N.B., QUE., ONT., MAN., SASK., ALTA., B.C.)

COMMENT - PRODUCED DURING MANUFACTURE OF PHOSPHATE FERTILIZER -  
OF INTEREST AS RAW MATERIAL FOR GYPSUM PRODUCTS MANUFACTURE,  
BUT CONTAINED RADIUM COULD DISCOURAGE USE.

USE - GYPSUM PRODUCTS MANUFACTURE\*  
SET-CONTROL AGENT, PORTLAND CEMENT\*\*

\* INVESTIGATED BY CANMET

\*\* INVESTIGATED BY OTHERS

TYPE - FLUOROGYPSUM

AMOUNT - 1 MILLION TPY (QUE., ONT.)

COMMENT - PRODUCED DURING MANUFACTURE OF HYDROFLUORIC ACID -  
OF INTEREST FOR GYPSUM PRODUCTS MFG. AND IN PORTLAND CEMENT

USE - GYPSUM PRODUCTS\*  
- PORTLAND CEMENT\*\*

\* UNDER INVESTIGATION BY CANMET

\*\* INVESTIGATED BY OTHERS

TYPE - SULFOGYPSUM

AMOUNT - (300,000 TPY IN 1980 IN QUE.)

COMMENT - TO BE PRODUCED BY QUEBEC TITANIUM DIOXIDE MANUFACTURERS IN EARLY  
1980'S BY NEUTRALIZING SPENT SULPHURIC ACID WITH LIMESTONE.  
PILOT-PLANT RESEARCH INDICATES HIGH-PURITY PRODUCT

USE - MANUFACTURE OF GYPSUM PRODUCTS\*  
SET-CONTROL AGENT IN PORTLAND CEMENT\*\*

\* UNDER INVESTIGATION BY CANMET

\*\* UNDER INVESTIGATION BY OTHERS

TYPE

- RED MUD

AMOUNT

- 1.5 MILLION TPY (QUE.)

COMMENT

- PRODUCED DURING MANUFACTURE OF ALUMINUM BY BAYER PROCESS, -  
SUBJECT OF MUCH RESEARCH, CANADA AND ELSEWHERE

USES

- PARTIAL REPLACEMENT FOR FLUORSPAR IN STEEL MANUFACTURE (POTENTIAL USE)
- MANUFACTURE OF BRICK AND BLOCKS (POTENTIAL USE)
- AS A PELLETIZING AGENT (POTENTIAL USE)

GENERAL COMMENTS

1. THE BULK OF THE MINERAL AND MINERAL-BASED WASTES, PERHAPS 90%, WILL NEVER BE UTILIZED, BUT WILL REMAIN A LIABILITY TO THE PRODUCER.
2. REMAINING 10% REPRESENTS ABOUT 40 MILLION TPY - CAN WE WORK TOWARDS FULL UTILIZATION OF THIS AMOUNT BY THE YEAR 2000?
3. To MEET THIS OBJECTIVE, WE REQUIRE
  - I BASIC BACKGROUND INFORMATION ON OCCURRENCE AND NATURE OF WASTES - CANMET REPORTS
  - II MORE INTEREST AND RESEARCH BY INDUSTRY AND GOVERNMENT
  - III INFORMATION EXCHANGE AND CO-OPERATION BETWEEN "PRODUCERS" AND "POTENTIAL CONSUMERS" OF MINERAL WASTES - WASTE EXCHANGE AND SEMINARS.

New Developments in Slag Utilization

Donald W. Lewis, Chief Engineer  
National Slag Association

ABSTRACT

Slags are produced in all metallurgical operations; with the greatest amounts generated by the iron and steel industry. The two general types of steel industry slags are: (1) blast furnace slag produced in the blast furnaces when the iron ores are reduced to molten iron, and (2) steel slags generated in open hearth, basic oxygen, or electric furnaces during the refining of iron to finished steel.

Blast furnace slags have been used to some extent as construction aggregates since the days of the Roman Empire, and as a cementitious material for some 200 years. At the present time, nearly all of the blast furnace slag produced in the U. S. is utilized, with the annual usage of 25 to 30 million tons. Production is in three general forms, determined by the cooling of the molten slag as it comes from the furnace. Air-cooled slag, solidified under atmospheric conditions, is the major product and forms an "All-Purpose Construction Aggregate", used instead of gravel and crushed stone in all types of construction applications. The principal applications are base courses and fills, railroad ballast, bituminous construction (where it provides excellent skid resistance) and as concrete aggregate (providing improved fire resistance and insulation properties). Expanded blast furnace slag is produced by treating the molten material with controlled quantities of water to produce a lightweight aggregate for use in concrete masonry units and structural lightweight concrete construction. Granulated slag is a quickly cooled, glassy product that has cementitious properties and can be used to replace portland cement when pulverized to suitable fineness. The cementitious applications of slag are of major importance in European countries, South Africa and Japan, while aggregate applications predominate in the U. S.

Steel slags have more limited applications than do blast furnace slags, but have been utilized extensively in recent years in several areas. Predominant applications have been in base construction, as railroad ballast, and in bituminous paving where this material exhibits outstanding skid resistance.

The various applications of slags have several benefits: (1) a material that would otherwise be wasted with high disposal costs is serving a useful purpose; (2) use as a lightweight aggregate and as a cementitious material conserves large amounts of energy necessary to manufacture the alternative materials and (3) natural resources that would otherwise be used are conserved. Slags should be considered to be "recovered resources" rather than "waste materials".

The most recent important development in slag utilization is the pelletizing process here in Canada. The pelletized blast furnace slags possess excellent characteristics as lightweight aggregates and are sufficiently glassy that they are also valuable as cementitious materials. The process is now being used in some eight nations, with the products going into cement manufacture, base course stabilization, concrete masonry units where it functions as part of both the aggregate and the cementitious material, and in structural concrete.

As costs increase for energy and for wasting materials, the use of blast furnace slags in cementitious applications and as lightweight aggregates is expected to increase since their greatest value will be realized in these areas. This will reduce the supplies available for uses such as base courses, railroad ballast and bituminous construction aggregates, and increased use of steel slags (and those from other metallurgical industries) in these applications will probably result. Future complete utilization of slags is essential from both economic and conservation viewpoints.

## COMMERCIAL APPLICATIONS OF FLY ASH

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and Industrial Waste Seminar

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Greetings from the United States where we also have substantial problems in the utilization of mining and industrial waste. When I talked to Mike Mocek in terms of finding out what it was I was supposed to cover in my talk, he sent me a letter which included the following statement, "talk about fly ash, its uses, potential applications, and problems." Truly each one of these items is a subject of its own, and I am going to have a little trouble covering the pertinent points in all of them.

Looking back to the thirty years I have been involved with utilization or disposal of many millions of tons of fly ash, I feel that although there have been notable successes, there have also been many frustrations, and unfortunately, today most of the fly ash is still being sent to landfill for disposal. However, over the years one of the favorable developments which is improving the utilization picture is the general attitude or philosophy that is taking place in the world around us. When I first started in this business, fly ash was called "soot." Later there was some excellent work done by Professor Davis of the University of California, as well as Mr. Weinheimer at the Detroit Edison Company, and, as a result, the word pozzolan crept into the language. It was found that fly ash had special properties that made it suitable as a material which had use in cementitious compositions. This initiated a major effort using fly ash as an admixture in portland cement compositions. Subsequently it was found that the pozzolan tended to react with lime that is released by portland cement during hydration. This discovery started a completely new program of lime/fly ash uses and, as a result, many millions of tons of fly ash have been applied to road construction and other structural applications using lime in place of portland cement.

Since these, and other uses, result in large energy savings (lime and

portland cement are highly energy sensitive products), there is now a major change in attitude regarding the acceptance of fly ash by the engineering profession. In the United States there is a serious effort being applied to classify fly ash as a national resource. In fact, several states have mandated that it should be so classified. As a result, fly ash is gradually being recognized as a basic raw material and not just a waste product.

Another development in this connection relates to the adoption of specifications by such agencies as the Federal Transportation Board, various regional and state highway departments, etc. The American Society for Testing and Materials and the American Concrete Institute have been very active in this connection, and there are current material and product specifications and methods of tests that delineate the type of materials which can be used for a variety of construction uses.

Statistics from a recent report by the National Ash Association, which generate data similar to those presented by Don Lewis relating to steel industry slag, is presented in Table I. These data show that in 1976 when the survey was completed, there was approximately 60 million tons of coal ash produced in the country, of which 42 million was fly ash. Of the 42-43 million tons, 5.7 million tons did find applications in the market place. A breakdown of the 5.7 million tons into areas where most of it was used indicated the following. The major use was in stabilization of roads, land reclamation, ecology dykes, and applications of this type. About 25 percent of the utilized fly ash went into those applications. The second largest use was as a supplement with portland cement in respect either to the use of it as a partial replacement of cement in concrete (to the extent of 16 percent), or in the formation of Type IP blended cement, or for use as the raw material in raw clinker

production (which indicated about 9 percent replacement).

Other applications include the use of fly ash as a mineral filler in asphalt and as raw material to produce lightweight structural aggregate by means of a sinter strand.

Unfortunately, as mentioned previously, most of the fly ash (approximately 85 percent) is still being hauled to a landfill or sluiced to lagoons as waste.

#### PROBLEMS WHICH RESTRICT COMMERCIAL USE OF FLY ASH

There are numerous reasons that fly ash is still not utilized in greater quantities at the present time. The first is the logistics of supply and demand which includes the reliability of available supply. For example, if a fly ash broker receives a contract for a job which requires delivery of large tonnages of fly ash and should the power plant suddenly schedule an outage of the boiler which shuts off the supply of fly ash, this action breaks down the credibility link between supplier and user, which effects further orders by this client.

Secondly, the question of uniformity has come up many times. Since fly ash is a by-product waste as far as the utility is concerned, there is a reluctance on the part of this industry to do a great deal of control of quality and this, of course, can create problems in terms of utilization. The brokers that have been most successful in the United States are, therefore, those individuals who have located specific sources of fly ash which have a relatively continuous supply of good quality material of adequate uniformity. Stating this in another way, it is apparent that there are really two kinds of fly ash being produced: one is the material that has the availability and quality that can be fitted into the market place; the other is the product that is

simply being sluiced or trucked to the dump which is almost impossible to reclaim and use in commercial applications.

Another major reason that fly ash is not more widely used relates to the question of economics and competition. It is quite costly to install handling, storage, and processing systems in order to produce a quality product. Furthermore, it costs considerable money to transport this material to job sites. In many instances, therefore, it is preferable to simply pump the material (with the bottom ash and other by-products) to a waste pond or landfill area. With respect to the question of competition, unfortunately for every process which could use fly ash, there is usually a product on the market with which it must compete. For example, as we heard this morning, slag is a material that can also be blended with portland cement and used as a cementitious additive in concrete.

Recently several new problems have emerged which can effect the fly ash utilization programs. Different forms of coal are now being used in pulverized coal burning operations, such as lignites and subbituminous coal. These materials produce ash with quite different properties; for example, some of them are cementitious themselves and tend to "flash set" as soon as they come in contact with water. Therefore, there is a great deal of difficulty in handling these fly ashes for current uses.

The environmental aspects of fly ash are also now playing a role in the United States. The question of whether or not any leachates are being discharged from the disposal ponds is now being given serious study by several federal agencies. And, in addition, because of control of SO<sub>2</sub> emissions from boilers, it is now necessary that newly constructed plants must install SO<sub>2</sub> scrubbers to control stack emissions. This requirement doubles the amount of

waste material coming out of the plant. The sludge that is produced from the scrubber has even greater volume than the amount of fly ash that is sluiced out to the pond.

#### RECENT DEVELOPMENTS IN FLY ASH UTILIZATION

Original construction practice for using lime/fly ash stabilized road base utilized mixed in-place methods. This procedure has been largely replaced by central plant mixed techniques. Figure 1 shows a typical plant using this method. The complete mix is supplied to the contractor who places the product on a previously prepared subbase (Figure 2).

Another development now being used is the lime/fly ash/aggregate road mixture in the preparation of a premix (Poz-O-Blend<sup>®</sup>) which results in a specially designed blend of lime and fly ash with proprietary additives. This mixture is shipped to the mix plant for production of a Poz-O-Blend aggregate mixture.

Figure 3 shows such a premix plant now in operation in Kansas City.

With respect to fly ash/portland cement applications, a number of plants are now producing a Type IP cement using fly ash either interground or interblended with portland cement. This practice saves considerable energy in the production of the end product of the cement company.

Figure 4 shows a plant in the United States which is converting the fly ash and SO<sub>x</sub> scrubber sludge into an environmentally acceptable structural fill material. This composition can also be used as a liner for disposal ponds, and as a base material in roads. Figure 5 shows the material being applied to a road project. Figures 6 and 7 show a landfill project for a California housing project. Figure 8 shows a power plant disposal pond for wastewater which was built using a non-leachable structural mixture of fly ash and scrub-

ber sludge.

The fly ash sludge mixture can also be used to dispose of municipal sewage sludge. Figure 9 shows the plant where some of the fly ash, sludge, and sewage sludge materials were mixed. Thirty percent of the mixture was sewage sludge. Figure 10 shows the material being spread over a land area and compacted with conventional compacting equipment. This process has been evaluated and approved by the U. S. Environmental Protection Agency as a suitable means of disposal of the sewage sludge.

Finally, I would like to mention a word or two about synthetic aggregates. As mentioned previously, the manufactured lightweight fly ash sintered aggregate is enjoying some success. However, the process is quite sensitive to the quality of the fly ash which is available at the plant, and this is probably one of the main reasons why it has not been used to a greater degree. On the other hand, if fly ash sludge mixtures are run through the pelletizing device in the lightweight aggregate plant, a pellet is formed that simply hardens on storage. This product has the advantage of being less sensitive to the quality of the fly ash. Further, the method does not need fuel as is required in sintering processes.

Figure 11 shows a batch of block that was produced in a commercial block plant using the fly ash/sludge aggregate. It has been estimated that an average sized block plant could use all of the aggregate made from the waste of a power plant of approximately 200 megawatt capacity. Thus should the power plant be located close to a concrete block plant, this is an application that could easily utilize all of the fly ash and scrubber sludge produced by the coal burning operation.

In conclusion, it can be stated that in spite of all the problems which

exist in utilizing fly ash, sufficient progress has been accomplished so that there will unquestionably be major improvements in the statistics presented in this report.

TABLE I  
ASH COLLECTION & UTILIZATION 1975  
(Million Tons)

Ash Collected

Fly Ash	42.3
Bottom Ash	13.1
Boiler Slag	4.6
TOTAL ASH COLLECTED - TONS X 10	60.0

Ash Utilized

Fly Ash	4.5
Bottom Ash	3.5
Boiler Slag	1.8
TOTAL ASH UTILIZED - TONS X 10	9.8

Percent of Ash Utilized

% Fly Ash	10.6
% Bottom Ash	26.7
% Boiler Slag	40.0
PERCENT OF TOTAL ASH UTILIZED	16.4



FIGURE 1  
LIME/FLY ASH/AGGREGATE (POZ-O-PAC) CENTRAL MIX PLANT



FIGURE 2  
POZ-O-PAC ROAD AFTER 12 YEARS OF SERVICE

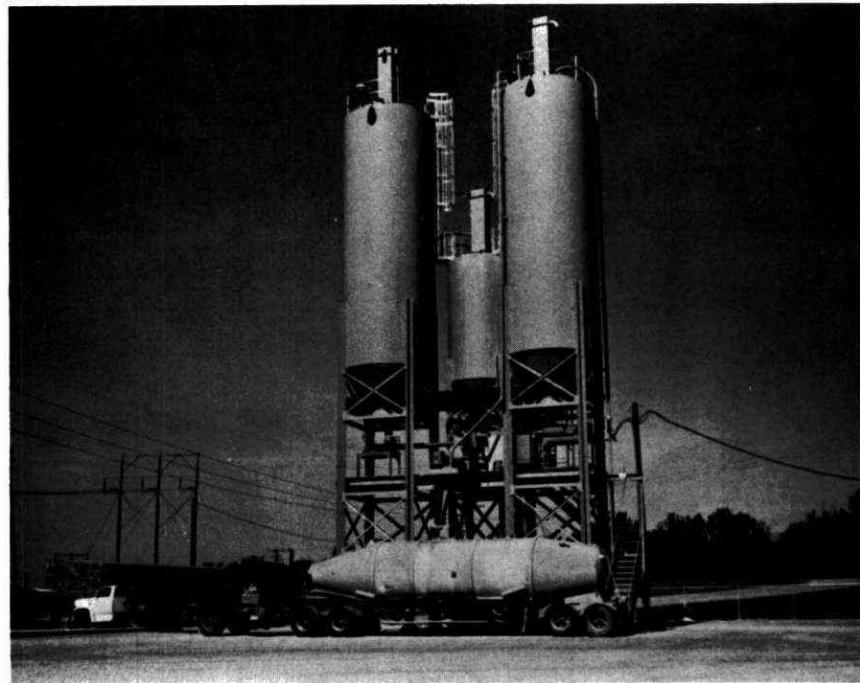


FIGURE 3  
LIME/FLY ASH (POZ-O-BLEND) MIX PLANT



FIGURE 4  
STABILIZATION PLANT (POZ-O-TEC) USING FLY ASH AND SO<sub>X</sub> SCRUBBER SLUDGE



FIGURE 5  
PLACING POZ-O-TEC ROAD BASE



FIGURE 6  
LANDFILL SITE PRIOR TO ADDITION OF POZ-O-TEC

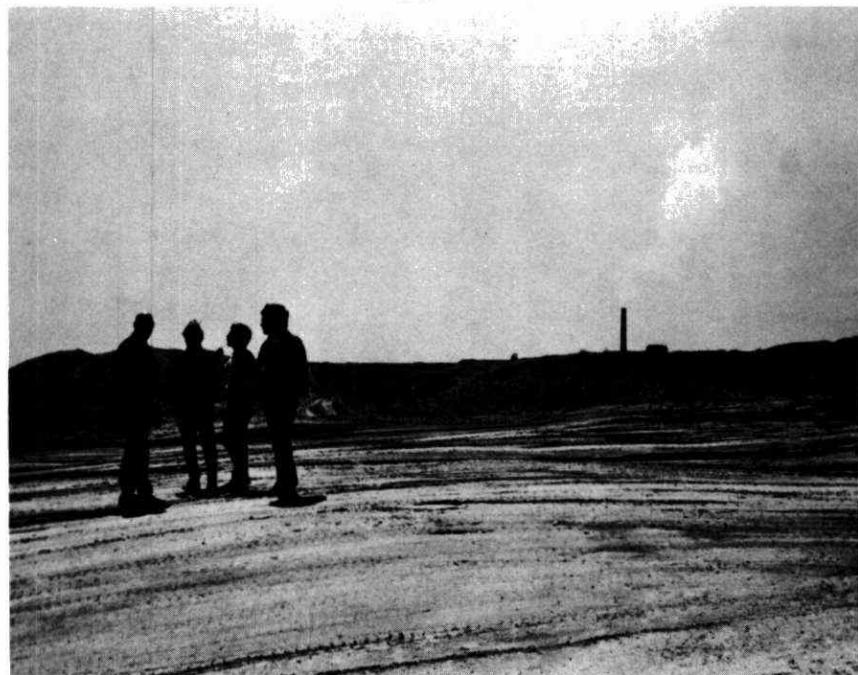


FIGURE 7  
COMPLETED LANDFILL AT SITE SHOWN IN FIGURE 6



FIGURE 8  
POWER PLANT WASTEWATER LAGOON USING POZ-O-TEC LINER

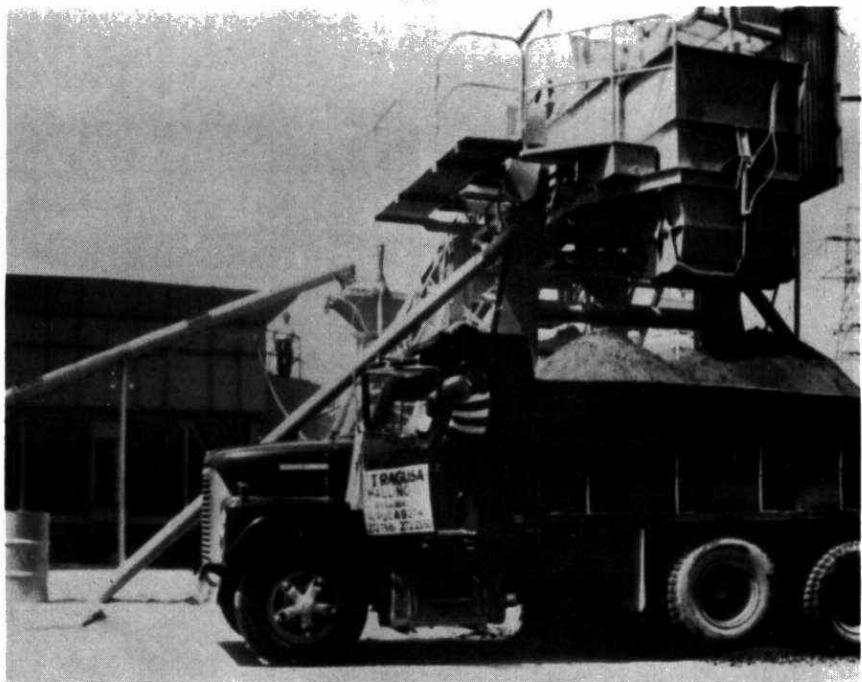


FIGURE 9

PLANT MIXING FLY ASH AND SLUDGE WITH MUNICIPAL SEWAGE (POZ-O-SOIL)



FIGURE 10

SPREADING OPERATION USING POZ-O-SOIL AS STRUCTURAL FILL

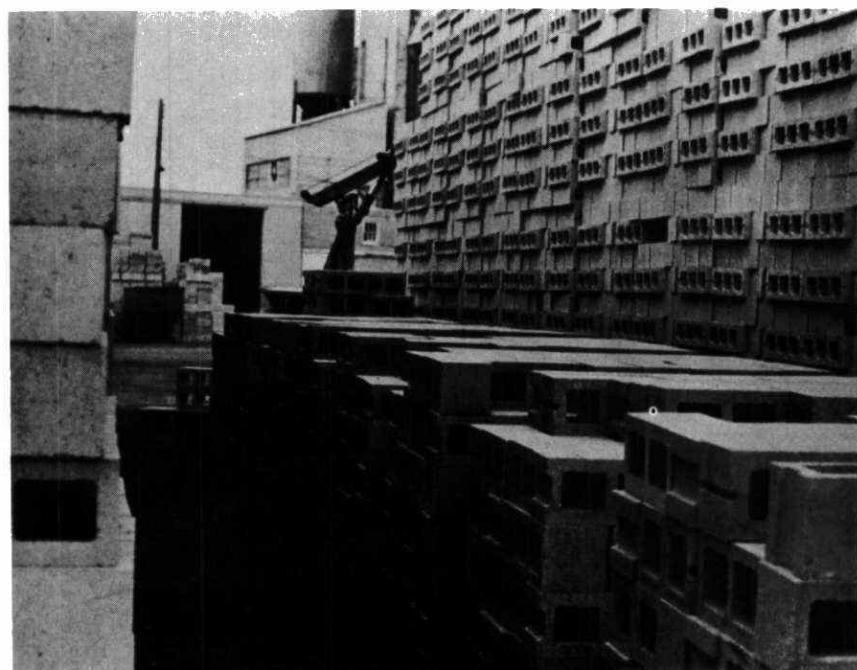


FIGURE 11  
CONCRETE BLOCK PRODUCED WITH COLD SETTING  
FLY ASH/SLUDGE SYNTHETIC AGGREGATE

UNIQUE APPROACHES TO  
WASTE UTILIZATION

by

H. Bergstrom

Bergstrom International Ltd.  
Consultants

presented at the

UTILIZATION OF MINING AND

INDUSTRIAL WASTE

SEMINAR

TORONTO, ONTARIO

OCTOBER 13, 1977

It was a most pleasing surprise to have been requested to present a paper at this conference and I am happy to be here today.

Waste materials have always been of great interest to us and we have found ourselves becoming progressively more involved in waste materials and energy conservation. Although I cannot really speak on behalf of my conferees however I am sure that they too have found it to be developing into a challenging field of engineering activity.

As an International Company we have come to the realization that other countries, especially the old world countries, are much more aware of the necessity of waste utilization and conservation. This awareness was well expressed by Professor Dr. Herbert Grunewald, Chief Executive of the Bayer Company, during an interview for the National Geographic Society Magazine. His statement appeared in the August 1977 issue in an article titled "West Germany Continuing Miracle. His comments were as follows:

"All our plants are modern, constantly renewed. And with these facilities are combined the know how from generations in the business. We make 6000 products, and we try and use 100 percent of the raw chemicals. Nothing should be wasted".

This is the philosophy we must all adopt so as to preserve our resources.

As consulting engineers we have found it difficult to obtain engineering contracts in waste materials and our difficulties are no doubt shared by other consultants.

We have taken a somewhat different approach over the last 4 years to the problem which is perhaps unique and novel in respect to the consulting engineering profession. Rather than try to obtain an engineering contract per se we request permission to study a client's waste materials at no cost to the client. We obtain samples etc. and develop the required process where necessary, do a preliminary feasibility study and find a client who would be interested in purchasing the processed waste for useful use. Once we have succeeded in putting together the complete package, we then approach our original client and sort out the financial arrangements whereby everyone benefits.

We are presently involved in 7 different waste projects, some are on an engineering contract lease.

For general interest I have selected 3 different examples which may be of interest.

EXAMPLE #1 - SYNTHETIC GYPSUM

During the course of an engineering project with one particular client, we became interested in the material that was in the waste ponds, which was synthetic calcium sulphate, which was a waste product from the manufacture of hydro flouric acid. With the permission of management we obtained random samples of the various wastes produced, which were synthetic calcium sulphate, iron concentrate and super fine silica in a slurry form. At the same time we established that our client would be interested in selling the waste if a market existed and if the conditions of sale were suitable, and that we would be renumerated if we did in fact solve their waste problem and establish a market. This was sufficient incentive for us to pursue the matter.

Once we had a positive analysis of the material, we discussed the analysis with people in the cement business, because it appeared to us on first observation that the material could possibly be used as a substitute for natural gypsum. We knew of various attempts to use the material for other purposes, however, we felt that the cement industry would be the most likely to start with. I suppose this was due, in some degree, to our past experience with the cement industry.

Natural gypsum  $\text{CaSO}_4 \cdot (\text{H}_2\text{O})_2$  is used as a retardant in the manufacture of portland cement. The amount of gypsum added is in the region of 3-5% by weight and is dependent on the  $\text{SO}_3$  content.

The following slide shows the typical analysis of the synthetic gypsum, as well as a typical analysis of natural gypsum, which was used by one of the cement producers.

GYPSUM - SLIDE #1

Of particular interest is the higher  $SO_3$  content of 46% in the synthetic gypsum, in comparison to 42.3% for natural gypsum. This means that, theoretically anyway, less of the synthetic material would be required. The indicated combined water of 15.2% appears low and actually higher figures have been recorded close to 20%. Natural gypsum again is comparable.

The fluoride of 0.13% is of particular interest and in the case of this material some of it appears in the form of hydroflouric acid, which makes the synthetic gypsum acidic, having a Ph of 5.5.

Neutralization can be easily established by the addition of calcium carbonate or lime. This problem may or may not be a factor depending on the operation of the specific cement plant. In the case of our client, neutralization results from the free lime in the clinker, as well as from the addition of calcium carbonate in the finish mill. We have not established the fluoride content, if any, in the natural gypsum, but intend to do so, as well as establish the amounts in the other raw materials used in the making of cement by the ultimate user of this synthetic gypsum. Usually the raw materials can contain  $.05\% \pm .03\%$  fluoride and fluorides have been added in some cases to help clinker formation. The increase in the fluoride content of the product in this case would be approximately 0.005%. Other elements which are undesirable are not detectable and are very low and very comparable with natural gypsum.

We provided samples of the synthetic gypsum to four (4) different plants. Interestingly, most of the plants did find the material acceptable chemically, but all objected to the free moisture content, which created a



Ontario

Ministry of  
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M7A 2E1

Dear Industrialist:

Enclosed is your copy of the Proceedings of the  
"Utilization of Mining and Industrial Waste"  
which was held on October 13, 1977 in Toronto.

In order to assess the interest and effectiveness  
of the seminars we would appreciate your comments  
as to whether these have been useful to you and  
also whether your company had an opportunity to  
utilize some waste materials.

Would you please take a minute, fill in the attached  
questionnaire and return it to the address indicated.

Thank you for your cooperation.

Yours very truly,

M. Mocek,  
Seminar Chairman

MM:cc  
Enc.

UTILIZATION OF MINING AND INDUSTRIAL WASTE

Did the seminar meet your expectations?

High

Medium

Low

Disappointed, why?

---

---

Did your company have an opportunity to utilize some mining or industrial wastes?

Yes

No

If yes, please fill in below:

Project	Wastes Utilized	Product from waste	Capital Expenditure

Attach description if required

Additional comments:

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Information supplied by:

Company Name \_\_\_\_\_

Address \_\_\_\_\_

Phone \_\_\_\_\_ Name of Contact \_\_\_\_\_

Please return to: M. Mocek  
Ministry of Industry and Tourism  
Industry Branch  
900 Bay Street  
Toronto, Ontario  
M7A 2E4

SYNTHETIC GYPSUM (TYPICAL) ANALYSIS

		%
COMBINED WATER (H <sub>2</sub> O)		15.2
SULPHATE (SO <sub>4</sub> )		55.0
(AS SO <sub>3</sub> )		46.0
FLUORIDE (F)		0.13
SILICON (Si)	1.0	- 3.0
TITANIUM (Ti)	0.05	- 0.1
ALUMINUM (Al)	0.2	- 0.5
MAGNESIUM (Mg)	0.002	- 0.005
MANGANESE (Mn)	0.001	- 0.003
IRON (Fe)	0.05	- 0.1
LEAD (Pb)	0.2	- 0.5
CHROMIUM (Cr)	0.001	- 0.003
ZINC (Zn)	n.d. (< 0.05)	
NICKEL (Ni)	n.d. (< 0.003)	
COBALT (Co)	n.d. (< 0.003)	
COPPER (cu)	0.002	- 0.005
TIN (Sn)	n.d. (< 0.001)	
CADMIUM (Cd)	n.d. (< 0.02)	
ZIRCONIUM (Zr)	0.08	- 0.2
VANADIUM (V)		(0.002)
BARIUM (Ba)	0.02	- 0.5
STRONTIUM (Sr)	0.002	- 0.005
SILVER (Ag)	n.d. (< 0.0002)	
SODIUM (Na)	n.d. (< 0.05)	
MOLYBDENUM (Mo)	n.d. (< 0.002)	
PHOSPHOROUS (P)	n.d. (< 0.2)	
LITHIUM (Li)	n.d. (< 0.1)	
BORON (B)		(0.001)
ARSENIC (As)	n.d. (< 0.1)	
ANTIMONY (Sb)	n.d. (< 0.004)	
ANHYDRIDE	n.d.	

THIS IS A TYPICAL ANALYSIS AND  
NOT A SPECIFICATION

PURITY

93.2+

NATURAL GYPSUM (TYPICAL)

	%
H <sub>2</sub> O	19.0
SO <sub>3</sub>	42.0 MIN
CaO	33.0
Fe <sub>2</sub> O <sub>3</sub>	0.4
Al <sub>2</sub> O <sub>3</sub>	—
MgCO <sub>3</sub>	0.36
NaCl	0.004
SiO <sub>2</sub>	3.0
ANHYDRIDE	2.4
PURITY	91.0

n.d.=not detected

material handling problem. Also, most people found that it absorbed water quickly and so it was established that the material required inside storage following drying.

For a number of reasons we chose in the end to pursue the subject with one plant and this was after approximately 200 tons had been sampled from the waste pond. This particular cement plant requires 40,000 tons/year of the material on a dry basis. This quantity we found to be nearly ideal as the material is produced at a rate approximately 15 to 20,000 tons/year and the existing stockpile is estimated to contain approximately 250,000 tons. This would then indicate a continuous supply for approximately 10 years, depending on plant output and production requirements. Having established the basic market client/customer relation and annual quantity, the economics of mining, drying and transportation were taken up and happily everyone stands to gain from the project.

- 1) The owner of the synthetic gypsum receives a profit from his waste material, as well as eventually eliminating the waste material and eliminating the need to expand pond facilities in the future.
- 2) The ultimate user saves money on the use of the material.
- 3) The user benefits from the savings realized by handling dried material. The natural gypsum also presented a handling problem for this plant as it, too, had a tendency to hangup in bins, etc., due to free moisture and fines.
- 4) Less retardant is required per ton of cement because of the higher  $SO_3$  content.
- 5) The consultants are also happy as the project has turned into success after  $2\frac{1}{2}$  years of research work and, of course, not to forget that finally renumeration is received.

A final test run of 60 tons is now in progress and everyone is positive about its expected results. Shipments of undried material are expected to start this year and the drying equipment will be operational during the second quarter of 1978.

In addition to the synthetic gypsum wastes there exists high iron fines from past roasting operations. The iron fines are highly suitable as an iron addition for making cement, as they contain no detrimental alkalies. This same plant would use approximately 7000 tons annually of the iron fines, which makes the entire project that much more attractive financially and environmentally.

The basic material flowsheet is as shown by this slide.

GYPSUM - SLIDE #2

Essentially the material will be reclaimed by a bulldozer fitted with a scoop and ripper. The material will be stockpiled using a stacking conveyor and the stockpiling will proceed six (6) months in advance of drying. This is to provide ample time for the free moisture to drain out to a minimum level. The drying system will be fed by the same bulldozer. Indirect heat dryers will be used so as to minimize on dusting possibilities, as well as provide good control over material temperature. The dryer will be fired by #2 oil and quite possibly augmented by electrical heating. The water vapour will be extracted by a water nozzle venturi which will also act as a scrubber. The resulting slurry will be returned to the main settling pond. This provides a closed circuit system thus eliminating the possibility of secondary pollution problems. The dried product, from the 100 ton product silo

(which will have adequate vent collectors, etc.), will be loaded into 37 ton tractor trailer trucks, which will be provided with covers to reduce the possibility of moisture pick-up as well as dust loss.

The total trucking distance, return, is approximately 150 miles. To add to the project viability, return truck loads of crushed stone are under consideration.

As a measure to conserve energy and fuel costs, plans are being discussed to locate the dryers at the cement plant. Waste heat from the vent fans on the clinker coolers could be used for the drying operation. The waste air is available at 400 to 500<sup>0</sup>F, which is an ideal temperature for the gypsum drying. The synthetic gypsum starts to lose some of its combined water at a temperature of approximately 125<sup>0</sup>C. Drying could be achieved in a standard rotary dryer, however, for this application we preferred to use indirect heating primarily as a means to minimize environmental problems.

GYPSUM - SLIDE #3

This is an aerial view of the two ponds. The pond in the upper part of the slide is the first pond into which the slurry is pumped and synthetic gypsum precipitate starts to settle out. Water is decanted out and sent to the second pond for further clarification and then carefully decanted out once completely clean. The pond in the lower portion is material that is well aged and is that which would be mined first. It seems that the precipitate must age for some time before the reaction of combined water is completed.

GYPSUM - SLIDE #4

Again an aerial view of the waste ponds and up at the top can be seen the waste iron deposits, which stand out as a reddish-purple material. The stockpiling will be located between the iron deposit and synthetic gypsum deposit.

GYPSUM - SLIDE #5

Here we can see the slurry pipe at pond #2, as well as the dykes which are made from the synthetic gypsum. Although the area appears very soft, it has sufficient bearing capacity to support a truck or bulldozer. This provides a good indication of the rapidity of settlement. The slurry pipe is moved as required so as to control the deposition of the precipitate.

GYPSUM - SLIDE #6

This dyke separates ponds #1 and #2 and has sufficient strength for trucking.

GYPSUM - SLIDE #7

Here one can see the surface of pond #2, which, as mentioned, will be mined first. Although this picture was taken directly following heavy rains, it is evident from the surface texture that the material is well settled. The surface water tends to drain out quickly, although the material is highly porous.

GYPSUM - SLIDE #8

The massiveness, as well as fineness, of the material is evident and the stratification lines from the settling action are quite pronounced. The material could be compared to sandstone or perhaps a cross between shale and pumice.

GYPSUM - SLIDE #9

This shows the available iron deposits clearly, alongside of which the stockpile and perhaps the dryer will be placed. There is very little impurities in the iron and so it is an ideal admixture for the cement plant operation. It is highly magnetic and very fine in nature. The material analysis indicates an  $Fe_2O_3$  content of approximately 80%.

As we continue to clean up our waste piles and effluent streams, we will no doubt find an increase in the production of synthetic calcium. Although all synthetic calcium sulphates are not suitable as a retardant for cement manufacturers, it is an avenue which should not be overlooked.

I am looking forward to hearing Mr. T. B. Lynch's talk, who is the next speaker, on Utilization of Gypsum and sulfuric acid.

EXAMPLE #2 - CHROME ORE FINES

Ferro alloy production in electric arc furnaces is predominantly based on lump ore feed. It is not practical to feed chrome ore fines into the electric melting system, because the particles are drawn out of the furnace by the fume system. As the world sources of chrome lump ore are very few and the exporting countries becoming more and more interested in processing their lump ores in their own smelters, foreign smelters will slowly be restricted to fines processing. Many plants in fact are processing chrome fines by first beneficiating the fines by grinding and concentrating for a higher chrome content and then agglomerating the concentrate by briquetting, as in effect in South Africa; or pelletizing as via the CoBo process, as developed in Sweden by SALA Manufacturing; and also pelletizing and firing in a grate preheater kiln system, such as marketed by Polysius and Allis Chalmers. No doubt there are other methods as well, such as plasma smelting, which appears to have promise.

Our interest in chrome fines resulted from an opportunity we had to study the development of the "MERUMITE" sands of Guyana. These sands are unique to Guyana and in their washed state they assay 76 to 82% chrome oxide ( $Cr_2O_3$ ) and 1 to 7%  $Fe_2O_3$ . As sand we knew they could not be fed to an electric furnace. After studying various slags, as produced by ferro chromium producers, we came to the conclusion that the "MERUMITE" sand could be mixed with common cement, excluding the calcium sulphate, to form lumps or agglomerates of any size. We tried the idea and it worked. Various additions, such as iron, carbon, etc., can be made as required to form the ideal furnace charge. We are presently waiting patiently for the road to be completed into the

interior of Guyana where the sands are found and hopefully mining operations will then come to pass.

This all resulted in our subsequently taking interest in a waste pile of chromium ore fines, which a refractory producer was unable to use. We again obtained samples and in this case we concentrated the fines by Wilfley tabling to remove some of the silica, which was reduced from 3.34%  $\text{SiO}_2$  to 2.27% or a silica recovery of 48.18%. The concentrate contained 39.0%  $\text{Cr}_2\text{O}_3$ . We took this concentrate and mixed it with common cement to form agglomerates, which were established to be satisfactory as partial feed to a furnace. We found that approximately 10% cement made a satisfactory agglomerate. We also made agglomerates using fines and carbon in which the mix consisted of: 65%  $\text{Cr}_2\text{O}_3$  fines

20% Coal

15% Cement

Unfortunately, this particular project did not proceed, because the chrome fines were finally usable as a refractory material following the silica recovery, and as yet the "MERUMITE" sands in Guyana cannot be reached by road. Irrespective, the project was successful in proving that chromium fines can be returned as partial feed by a very simple cementation process.

We were pleased to hear from Mr. W. D. Winship of Middelburg Steel and Alloys, in South Africa, that they had actually recently considered the same process, but finally elected to use briquetting for their particular installation, as 100% briquet feed.

We hope that this simple procedure will spark some interest among some of the Canadian Mining Companies who hold claims on lowgrade chrome ores to run some tests on their deposits with the idea of possibly starting the operation in a small way, but at least starting.

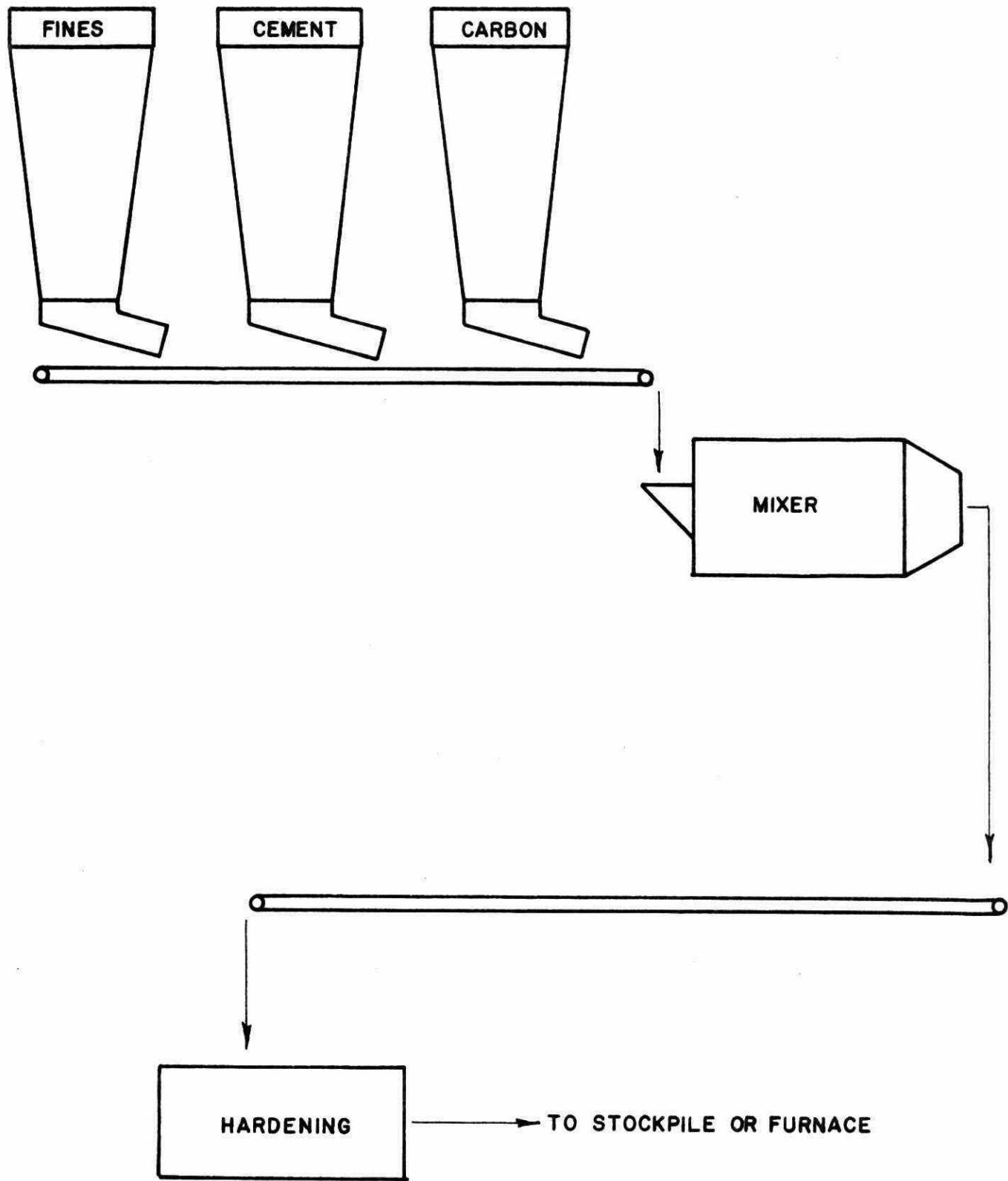
FERROCHROME ALLOY

METALLURGICAL BALANCE

Material	Wt. Kg	Cr %	Cr Kg	Fe %	Fe Kg	SiO <sub>2</sub> %	SiO <sub>2</sub> Kg	CaO %	CaO Kg	MgO %	MgO Kg	Al <sub>2</sub> O <sub>3</sub> %	Al <sub>2</sub> O <sub>3</sub> Kg	Cr:Fe Ratio
Turkish Lumps	800	33.6	268.8	10.9	87.2	5.5	44	0.6	4.8	17.5	140	12.0	96	3.08
Turkish Fines	200		67.2		21.8		11		1.2		35		24	3.08
Cement	44.1			3.0	1.3	22.0	9.7	64.1	28.3	1.4	0.6	5.5	2.4	
Silica (95%)	144.6						137.4							
Coke	190						17						6	
Coal	60						4						1	
Bauxite (85%)	6												5	
Total		91% Rec.	336	95% Rec.	110.3		223.1		34.3		175.6		134.4	
In Alloy			305.8		104.8		60.4							
In Slag			30.2		5.5		162.7		34.3		175.6		134.4	

20% Fines  
 80% Lumps  
 15% Cement in Pellet  
 20% Coal in Pellet

CEMENTATION PROCESS FLOWSHEET  
FOR  
CHROME FINES



ALLOY SPECIFICATIONS: Charge Chrome

Cr .....	64%
C .....	8.2%
Si .....	5.9%

CALCULATED ALLOY ANALYSIS:

Cr .....	305.8 Kg .....	64%
Fe .....	104.8 Kg .....	21.9%
C .....	39 Kg .....	8.2%
Si .....	28.2 Kg .....	5.9%
<hr/>		
	477.8 Kg	100%

SLAG CALCULATION:

CaO .....	34.3 Kg .....	6.1%
SiO <sub>2</sub> .....	162.7 Kg .....	29.2%
MgO .....	175.6 Kg .....	31.4%
Al <sub>2</sub> O <sub>3</sub> .....	134.4 Kg .....	24.0%
Cr <sub>2</sub> O <sub>3</sub> .....	45 Kg .....	8.0%
FeO .....	7.1 Kg .....	1.3%
<hr/>		
	559.1 Kg	100%

$$\text{MgO/Al}_2\text{O}_3 = 1.3$$

$$(\text{MgO} + \text{CaO})/\text{Al}_2\text{O}_3 = 1.56$$

FIXED CARBON REQUIREMENT: (Turkish Lumps and Fines)

For:  $C_r$        $305.8 \times 0.346$  - 105.8 Kg

$F_e$        $104.8 \times 0.215$  - 22.4 Kg

$S_i$        $28.2 \times 0.855$  - 24.1 Kg

C in alloy      - 39.0 Kg

189.3 at 100% Fixed C

Total at 103% Fixed Carbon ..... 195 Kg

FLUX CALCULATION:

Slag Weight ..... 559.1 Kg

$SiO_2$  in Alloy ..... 60.4 Kg

$SiO_2$  in Slag ..... 162.7 Kg

Total  $SiO_2$  ..... 223.1 Kg

Slag /Alloy Ratio ..... 1:2

EXAMPLE #3 - DISTILLERS DRIED GRAINS

WITH SOLUBLES

In the making of Canadian Whiskey and similarly flavoured alcoholic drinks, various mixtures of grains are fermented by the addition of yeast under closely controlled conditions in large fermentation tanks. Typical grains used are corn or milo, rye and malt, and others depending on the final product. Following fermentation the fermented mash is pumped to the primary distillation column, or better known as the beer still in the distillery business. Here the alcohol is distilled off and a spent grain slurry is left over, which contains approximately 6% solids. This waste slurry is termed stillage or slop. In the past the slop was wasted, however, now it is processed in "dry houses". This is not always the case in developing countries.

I had the pleasure of setting up a "dry house" for Canadian Schenley Distilleries, in Valleyfield, which was a most interesting waste materials project. Although it is not related, or at least directly, to the mining industry, it could have application in the mining industry for concentrating slurries, and, also, it does fall under the general topic of Industrial Waste. For these reasons, I felt it could be of interest and it does show how a rather messy waste material can be turned into a valuable product.

The "dry house" processes the slop and produces from it a dry product called "Distillers Dried Grains with Solubles". The product is sold as feed for livestock and contains many vitamins, as well as a protein content of over 25%.

The Valleyfield dryhouse was originally designed for a production rate of a distillery capacity of 4000 bushels per 20 hour day. Subsequently, the capacity has been increased to 6000 bushels.

The design criteria for the 4000 bushel plant is as follows:

4000 BUSHEL/20 HOUR  
DRY HOUSE DESIGN PARAMETERS

	<u>% SOLIDS</u>	<u>USGPH</u>	<u>LBS/HR</u>
Slop	6.7	6,00	---
Screen cake	10.6	3,200	---
Thin from screens	3.8	4,400	---
Thin from press	3.8	1,720	---
Press cake	35	---	4,000
Evaporator feed	3.8	6,120	---
Syrup from evaporator	30	700	6,460
Recycle grains	90	---	9,790
Dryer feed	60	---	20,250
Dryer output	90	---	13,510
Product to silo	90	---	3,720

Evaporator Operation

Water evaporated	44,340
Steam used	18,100
Cooling water	7,040

Evaporator efficiency approximately 2.5 $\frac{\text{H}_2\text{O}}{\text{lb steam}}$ .

Dryer Operation

Effective product rate	3,780 $\frac{\text{#}}{\text{hr}}$
Water evaporated	6,740
Heat imput gross	12,000,000 BTU/HR

The basic flowsheet is as per the following:

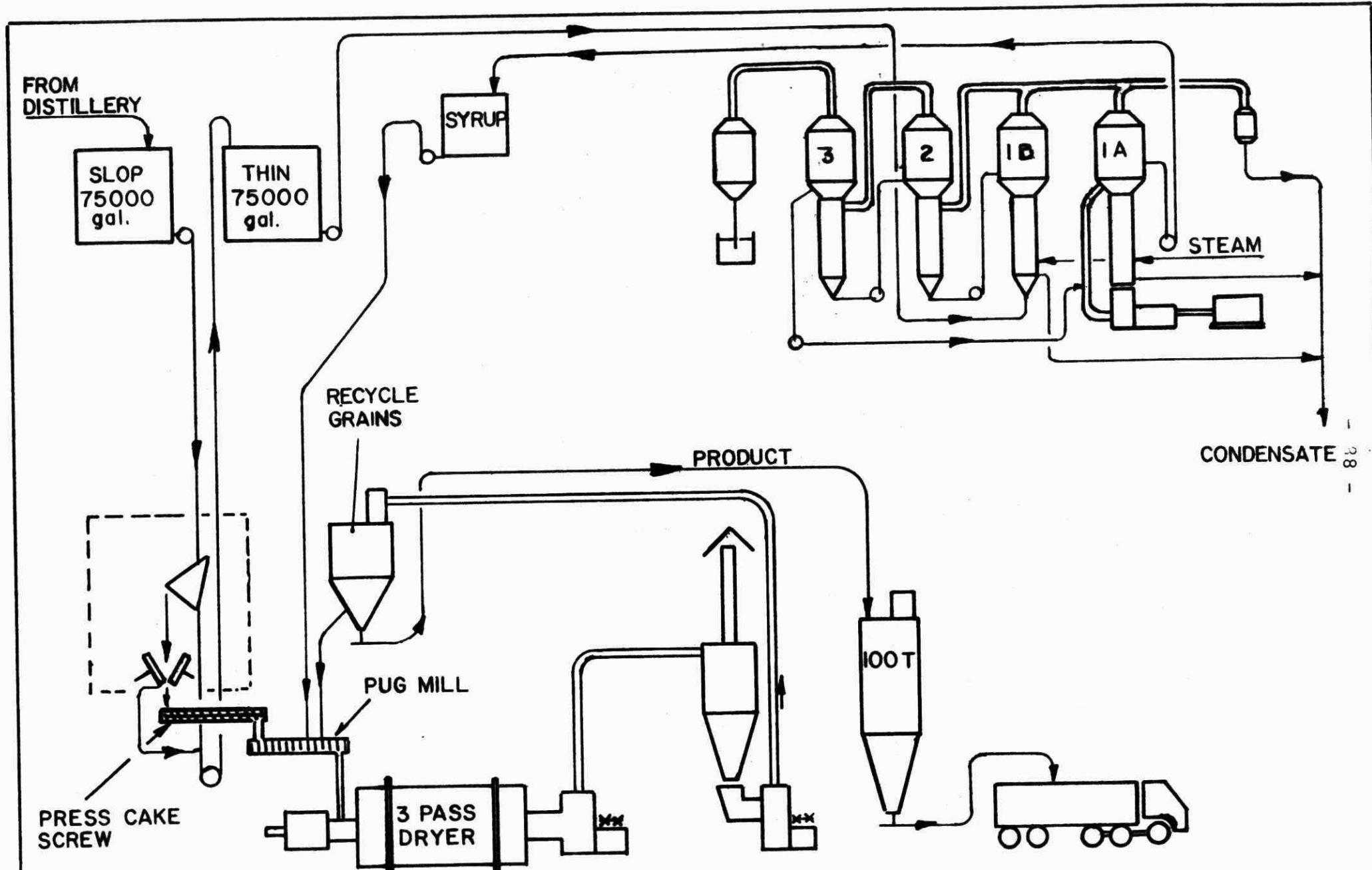
Dryhouse #1 - Schematic

The slop is pumped to two "Rotex" grating screens, which have a 50 mesh screen cloth. The rate of flow to each screen is regulated by a flowvalve. The coarse solids pass directly to one "Davenport" rotating disc press which squeezes out the water. The speed of the press is adjusted to the capacity and operation.

The thin stillage from the screen and press is collected and pumped to large storage tanks. From the tank the thin is pumped to multiple effect evaporators, which concentrate the thin to a syrup containing 30% solids. The evaporators are a triple effect with the first two combined and to which steam is supplied to effect boiling. The vapour from 1A and 1B are used to heat evaporator #2 and from the 2 the vapours are used for evaporator #3. Number 3 is maintained under a vacuum by a barometric condenser. The evaporators were supplied by the Sevenson Evaporator Company. (See next page for Evaporator specifics.)

The syrup is pumped to a syrup tank from where it is pumped to a pug mill which receives press cake as well as recycle grains. The three different materials are well mixed in the mill prior to discharge into the rotary dryer.

The rotary dryer is manufactured by the Heil Dryer Company, and is a 8½' diameter x 25' long with 3 passes, which means that the material passes through the dryer three times. Number 2 oil is burned in the combustion chamber and the inlet gas temperature is approximately 1500°F. The product leaving the dryer is at 200°F and contains a maximum of 10% moisture. The dryer



## **DRYHOUSE SCHEMATIC**

The Evaporator specifics are:

1A	-	292	-	1" DD x 18' long tubes	1375 sq. ft. total area
1B	-	131	-	1 $\frac{3}{4}$ DD x 20' long tubes	1200 sq. ft.
2	-	226	-	1 $\frac{3}{4}$ DD x 20' long tubes	2070 sq. ft.
3	-	226	-	1 $\frac{3}{4}$ DD x 20' long tubes	2070 sq. ft.

exhaust fan carries the product in air suspension to the product cyclone where the combustion products and water vapour are exhausted and the final product drops to a second fan. This fan cools the product as it is conveyed by air to the recycle bin. A recycle ratio of approximately 3 to 4 of the actual product quantity is maintained in the dryer. This prevents the grains from becoming overly sticky and allows them to pass through the dryer and subsequent material handling systems.

The final product from the recycle hopper is blown to the product silo from where it can be transported by truck or rail.

The entire system is automated and requires little attention on the part of the operator.

Since the original operation was installed, the Rotex screen and Davenport press equipment have been replaced by a Sharples 40 HP, 4000 RPM, centrifuge. This has eliminated the maintenance on screen cloth, as well as saved considerably on plant space. To keep the schematic simple, the second dryer, as well as the vent bag collector, are omitted.

The following slides provide a general view of the operation:

DISTILLERY - SLIDE #1

This aerial view shows the compaction of the complete plant. The slop and the tank and product silos are in the foreground. The dryhouse is on the right of the boiler house and attached to it.

DISTILLERY - SLIDE #2

This shows the main offices of Schenley Distilleries, in Valleyfield, and if you are out that way I am quite sure they would be pleased to show you around, as they are very friendly people running the plant.

DISTILLERY - SLIDE #3

The slop from the distillery is first pumped into these two stainless tanks. At times part of the stillage is returned to the distillery.

DISTILLERY - SLIDE #4 Stillage

This shows the stillage overflowing from the set back tank to the slop tank from where it is pumped to the large slop storage tanks.

DISTILLERY - SLIDE #5 Stillage

Here one can see the sort of soup the stillage really is and one can imagine the waste problem this would present, without a dryhouse.

DISTILLERY - SLIDE #6 Tankage

The large tanks are the main slop and thin tanks. The product silo is on the side and the white plume is the moisture which has come from the dryer product cyclone.

DISTILLERY - SLIDE #7 Centrifuge

The slop is pumped to Sharples centrifuges, which separate the slurry into a thin containing approximately 4% solids and a thick containing 70% solids. As mentioned, the centrifuge replaced the original

screen press convolution.

DISTILLERY - SLIDE #8      Centrifuge

This is a second view of the centrifuges of which there are three.

DISTILLERY - SLIDE #9      Pugmill (Bad Slide)

Regrettably the pugmill is not very evident in this slide. It is of the twin shaft type with stainless paddles. Size is approximately 3' diameter x 10' long.

DISTILLERY - SLIDE #10      Evaporators

The heat exchanger section of the evaporators, or bottom part is evident here. The long horizontal preheater wrapped in aluminum insulation was added when the capacity was revised to 6000 bushels.

DISTILLERY - SLIDE #11

The vapour heads of the evaporators are clearly shown. Again, all is stainless steel.

DISTILLERY - SLIDE #12

The syrup in the evaporator number 1A is force circulated by a steam turbine driven pump.

DISTILLERY - SLIDE #13

The barometric condenser is directly connected to the vapour head of 1A evaporator and operates with cold water. The vacuum it draws is approx-

imately 26" to 27".

DISTILLERY - SLIDE #14      Dryer Feed

The feed to the dryer, prior to having mixed with the recycle grains and syrup, has the appearance and consistency of wet grains, which, of course, it is.

DISTILLERY - SLIDE #15      Dryer Feed Pipe

The wet feed from the pugmill drops down the chute into the neck of the rotary dryer. The combustion chamber is on the left side and the gases in the throat are at 1500°F as they carry the wet grains into the dryer proper. Conveying in the dryer is effected primarily by the air stream and tumbling created by lifters.

DISTILLERY - SLIDE #16 (Dark Slide)

View of the combustion chamber which is a normal unit.

DISTILLERY - SLIDE #17 (Dark Slide)

The product from the dryer is conveyed out to the primary product cyclone by the fan.

DISTILLERY - SLIDE #18

The product from the primary cyclone is blown to this secondary cyclone and recycle hopper by a secondary fan. All fans used are of the simple paddle wheel type.

DISTILLERY - SLIDE #19      Controls

The complete dryhouse operation is automated and controlled from this control room.

DISTILLERY - SLIDE #20      Product

DISTILLERY - SLIDE #21      Product Silo

The final product is blown into this 100 ton steel storage silo.

For general interest, the grains sell at around \$120. to \$160./short ton, depending on the market conditions and also the protein level. The dryhouse operation has turned out to be a good viable business and is another example of what waste materials processing can mean.

THE PHOSPHORIC ACID PLANT as a GENERATOR of and a SINK for  
WASTE MATERIAL

by

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presented to

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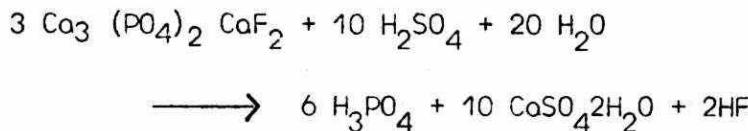
THE PHOSPHORIC ACID PLANT as a GENERATOR of and a SINK for WASTE MATERIALS

CIL's operations at Courtright are located on the St. Clair River some twenty miles south of Sarnia. The site is a large, modern fertilizer complex centred on the production of Ammonia and Phosphoric Acid but including facilities for the production of nitric acid, ammonium nitrate, urea, and ammonium phosphate. Because of the nature of our product, the large scale of operation and the location on one of the main arteries of the Great Lakes waterway, there is a risk of environmental damage. CIL recognized this potential and all the Plants were designed to meet the existing environmental criteria. In addition, it began extensive air and water surveys some eighteen months before manufacturing operations began in 1966 and has continued them since that time. Because of this, we have been able to assess CIL's impact on the surrounding environment. Further safeguards included a sophisticated network of instruments in both the main outfall and individual plant sewers to alert operating personnel to immediate problems.

All of the protective systems have worked well, but inevitably various problems have arisen through the years due to changes in production capacities, revisions to regulations and greater public concern about the latent effects of chemicals. Solutions to these problems have been found, many of them based on the recovery of what were originally considered 'waste streams'. My purpose this morning is to describe some of the successes and failures in resolving our own, and in one instance, another industry's 'waste' problems.

When I learned that I was to address an audience made up for the most part from the mining fraternity, I wondered how I could correlate our operations at Courtright with your own interests. Most of our Plants, such as the 1000-ton/day Kellogg Ammonia Plant are sophisticated chemical-producing plants.

The one Plant we can associate with mining operations, is the Phosphoric Acid facility which is based on the reaction between sulfuric acid and phosphate rock to produce gypsum and phosphoric acid :

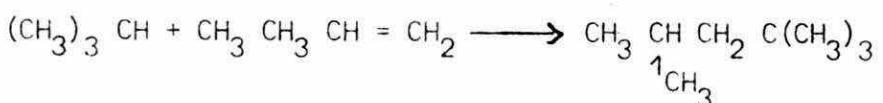


The phosphate rock used by CIL is stripmined in Florida and moved by rail to Courtright. The sulfuric acid is railed from Sudbury where it is recovered from smelter gas at International Nickel's nickel-processing plants. (Indeed this is our first example of waste recovery.)

Phosphoric acid manufacture in North America is based, I believe, exclusively on the dihydrate process. This means that the gypsum by-product contains two moles of water of crystallization as compared to the  $\frac{1}{2}$  mole in calcium sulfate hemihydrate which will be referred to later. A typical process for a dihydrate plant is outlined in Figure 1 and various steps in the process shown in the following slides. Thus the phosphate rock is ground in a ball mill before being digested with sulfuric acid in the attack tank. Although the prime objective of the process is to recover phosphoric acid, process control depends almost exclusively on the formation of a readily filterable gypsum. In practice, this is accomplished by carefully controlling the reaction temperature first by cooling the incoming diluted sulfuric acid and secondly, by flash cooling the slurry in the attack tank. Failure to do so, results in a 'difficult-to-filter' form of calcium sulfate. Filtration is usually carried out in a rotating pan filter, from which the filtered gypsum is pumped for disposal to gypsum ponds. The Phosphoric Acid filtrate is subsequently concentrated under vacuum and then reacted with ammonia in a granulation plant to diammonium phosphate. At Courtright, the evaporation facilities include scrubbers for the recovery of fluosilicic acid. This is sold to municipalities for the fluoridation of water supplies. I should also

point out that phosphate rock contains a small amount of uranium. This can be recovered economically if the scale of phosphate operations is large enough and a number of extraction plants are currently being built in the United States.

As mentioned previously, the sulfuric acid used in our phosphate operations stems for the most part from CIL's plants at Copper Cliff. These plants have a nominal capacity of about 1,000,000 tons/year, much of which is used in applications other than fertilizer manufacture. One of the most interesting in this area of non-lead gasoline is its use as a catalyst in alkylation processes at petroleum refineries. This involves the synthesis of high octane gasolines from branched unsaturated hydrocarbons such as butylene and isobutane:



The sulfuric acid process is economically more attractive from a capital investment point of view than a competitive process based on hydrofluoric acid, but until recently, the problem of disposing of the residual sulfuric acid after the reaction, has frequently nullified this advantage. The acid is an evil smelling liquid with a large organic, occasionally tar-like, content. Over the years, CIL has tried to find uses for this material as a service to its customers but a measure of the magnitude of the odour problem can be gained from the failure of one plant experiment. Virgin sulfuric acid was modified by two percent alkylation waste sulfuric acid and used as feed to the phosphate process. The smell forced abandonment of the trial within ten minutes. In retrospect this should have not been too surprising, as looking through old CIL files recently, I noted that correspondence on this particular problem had existed since the mid-1950's. The picture has now changed because in June of this year, we commissioned a commercially-sized plant to treat

alkylation waste acid and utilize it effectively as feed to the Phosphoric Acid Plant. The plant has worked at design capacity since start-up processing more than 100 tons of acid daily.

The process itself was devised by CIL's Chemical Research Laboratories and developed by Lambton Works' Technical Department. It is based on four years of pilot plant work in which some 25,000 tons of waste acid were recovered in the final year. As with most attempts to treat this waste acid, the CIL process is based on oxidising the offensive organic compounds. An original scheme was based on reacting the sulfuric with steam under pressure, thus using the high temperature and sulfuric acid itself to destroy the organics. Unfortunately, as in many cases, the reaction was successful on a small scale, but could not be contained in the scaled-up version. The current and successfully operating process involves reacting the organics with nitric acid. Carbon is formed and this is fed still mixed with the treated sulfuric acid directly to the phosphoric acid attack tank. Ultimately, the carbon is removed with the gypsum on the Prayon filter and disposed of in the gypsum ponds. Fumes from the process contain sulfur dioxide, nitrogen oxide and low-boiling organics. Any organics that pass through the scrubber are destroyed in an incinerator.

The slides show the reactor, the scrubber, and recirculation system, the incinerator which incidentally was manufactured by the Canadian firm, Trecan, and the control panel, which is by now an integral part of the phosphoric acid plant. The new facility will handle all of the alkylation waste acid produced in Canada and is in our opinion a prime example of an effective use of waste material. Phosphate operations in Canada are at a competitive disadvantage when compared to the large-scale Florida operations located adjacent to phosphate deposits. The use of waste acids can be used to (marginally) counteract this disadvantage. Such acids are not restricted to

alkylation waste. We routinely process chlorine drying acids and that recovered from nitration processes without the need for pre-treatment.

My second example of the economical recovery of waste, is again based on the use of a phosphoric acid plant as a sink, but this time, the material recovered is ammonia. The modern ammonia plant is based on the reformation of natural gas to produce hydrogen, which is then partially reacted with air to give the necessary synthesis ratios of hydrogen and nitrogen. ALL such plants have waste condensate streams which are contaminated with ammonia and some organics.

Table I lists a typical analysis for ammonia plant condensate from the CIL 1000 ton/day Kellogg Ammonia Plant -

TABLE I

Analysis of Ammonia Plant Condensate

Ammonia	700 ppm	Methylamine	25 ppm
Methyl Alcohol	1000 ppm	Dimethylamine	25 ppm
Carbon Dioxide	2000 ppm	Trimethylamine	25 ppm
Flow	220 gpm		

When production operations began at Courtright in 1966, the condensate was directed to our gypsum ponds as a temporary measure and subsequently to two, 1,400-foot deep wells. When regulations for deep wells were changed, we investigated alternate solutions. One common practice in the industry is to remove the ammonia from the condensate by steam stripping. In our case, this answer has two drawbacks, viz-a-viz, high energy costs and the offensive fish odour of methylamines as they are stripped with the ammonia. Consequently, we focused our attention on the ion exchange treatment of condensate to remove the ammonia and methylamines before discharging the treated condensate to the river.

Here again, the idea is not new. Ion exchange is used in a number of plants to treat ammonia waste streams; the most widely-reported being the Central Farmers Plant at Harrison, Tennessee. This particular unit is based on Chem-Sep

technology, involving mobile flows of anion and cation resins which are continuously charged and regenerated. In the Central Farmer's application, nitric acid is used as the regenerant, the consequent ammonium nitrate being used as a component of liquid fertilizers. By comparison, the ion exchange process used for this application at Courtright is relatively straightforward. It involves two conventional static cation resin exchangers and the use of sulfuric acid as regenerant. The resultant ammonium sulfate solution is fed to the Phosphoric Acid Plant, where it replaces part of the sulfuric acid used in rock digestion. As the phosphoric acid is all subsequently ammoniated to di or mono ammonium phosphate, more than 700 tons of ammonia are recovered each year from the 300 gpm condensate streams.

Although I have cited two successful examples of the utilization of waste, I would be remiss if I neglected to discuss the phosphate industry's notable failure to solve a problem of its own making. For every ton of phosphate rock digested in a dihydrate process, more than 1.4 tons of gypsum are formed. As far as I am aware no significant use has been found for this material in North America. At Courtright, we must discard and contain more than 1,400 tons of gypsum daily. The figures for Canada and the United States generally are:

TABLE II

Availability of Waste and Mined Gypsum

	<u>Canada</u>	<u>U.S.A.</u>
Waste Gypsum	1.8	22 million tons/year
Mined Gypsum	2.1	156 million tons/year

Disposal practice at the CIL Plant and the IMC Plant at Port Maitland is to pump the slurry to gypsum ponds where it settles out and the clarified water re-cycled for re-use in the Phosphate Plant. In New Brunswick, the gypsum is pumped out to sea. Gypsum has greater solubility in salt water than in fresh

water (3.5 g.p.l. as compared to 2.4 g.p.l.). Incidentally, recent discussions with scientists at I.C.I.'s extensive water research facilities at Brixham in Devon England who have studied the effects of gypsum discharged into the Bristol Channel for several years, indicate that maritime disposal has no observable, undesirable effects on marine life.

There are of course several potential uses for phosphogypsum. A partial list includes its use as a raw material for the plaster and cement industries, for sulfuric acid and ammonium sulfate and for a number of minor applications such as the treatment of dry soils or its combination with fly ash as a foundation material for roads. In North America the relative abundance of gypsum coupled with the low cost of sulfur and ready availability of sulfuric acid recovered from ore smelting, has discouraged an interest in the development of recovery processes for gypsum. Experience abroad has been somewhat different. Interest in Europe has ebbed and flowed, but a number of plaster and plasterboard, as well as building block plants have been built. Their success has perhaps been more cyclical than that of the phosphate industry itself. Two small plants are operating in Germany, but CIL's parent company, I.C.I. which operated two plaster and plasterboard plants based on phosphogypsum for several years, closed them in the early seventies. The only permanent reuse of chemically-produced calcium sulfate, has been in Japan, where there is relatively little natural occurring gypsum. The chemically-produced material is consequently used extensively, but even here (in Japan), calcium sulfate from plastic plants and sulfur dioxide recovery is preferred to the less-pure phosphogypsum. The demand is so great however, that phosphoric acid technology has developed along different lines in Japan than in North America and Europe in order to produce a relatively pure calcium sulfate.

In the production of plaster, gypsum is ground and heated to between 120 - 190° C to convert it to hemihydrate. This reverts to gypsum on settling. Some plasters

set very quickly when mixed with water and retarders are added to overcome this disadvantage. The major problem in utilizing phosphogypsum is the adverse effect of its impurities. Its analysis is compared with natural gypsum in Table III, where it can be seen that the major impurities are phosphates and fluoride:

TABLE III  
Typical Analysis of Gypsum

	<u>Natural Gypsum %</u>	<u>By-Product Gypsum %</u>
$\text{CaSO}_4 \frac{1}{2}\text{H}_2\text{O}$	6.7	NIL
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	92.4	92.8
$\text{Ca}_3 (\text{PO}_4)_2$	NIL	2.3
$\text{CaF}_2$	NIL	2.7
$\text{S}_1\text{O}_2$	.4	1.0
$\text{Fe}_2\text{O}_3$	.2	.01
$\text{Al}_2\text{O}_3$	NIL	0.8

The phosphate and soluble phosphate in phosphogypsum affect the setting rates and hardening rates of plaster, essentially making them unpredictable; whereas, fluoride, interferes with the adhesion between plaster and paper. Consequently, all such contaminants must be removed, or at least neutralized to make them inert. In practice, this is complicated by the low solubility of gypsum in water. As a result, it cannot be recrystallized, and must be converted by heating to the hemihydrate. The interchange between calcium sulfate and hemihydrate releases the co-crystallized impurities which can be readily separated. Most modern processes for recovering gypsum are based on this concept.

Two such processes are those designed by I.C.I. in England and Guillini in West Germany. The I.C.I. process (see Fig. 3) basically involves slurring

the gypsum with water, neutralizing the excess acidity and filtration. The filtered gypsum is dried under carefully-controlled conditions to the hemihydrate, which after cooling is ground to increase product surface area. A flowsheet for the Guillini process is shown in Figure 4. The gypsum is washed with water, and additives added to buffer the solution and floatate organic impurities. This partially purifies the gypsum, which is then pumped to an autoclave to convert it to the hemihydrate. The product is subsequently filtered and can be used directly to form building blocks or dried for subsequent use in plasterboard or cement manufacture.

It is claimed that operating costs for the Guillini process compare favourably with the cost of mining and calcining natural gypsum. Very rough calculations using publicized data and 1976 utility costs are shown in Table 4 and support this argument (i.e., roughly \$23/ton for each process). Nevertheless, there still remains the major difficulty of rationalizing the conflicting demands of the phosphoric acid and gypsum recovery plants. For example, if the rock feed to the phosphoric acid plant is changed, the entire process conditions in the gypsum plant must be adjusted to compensate for the altered gypsum characteristics. Such demands complicate process operations and of necessity, the phosphoric operation is asked to control its gypsum characteristics. As every phosphate dihydrate plant manager knows, this is an impossible task if he is to run his operations economically. It is precisely this difficulty that has forced the closure of several gypsum recovery plants.

As noted previously, the demand for chemically-formed gypsum in Japan and the relative absence of naturally-occurring product has resulted in changes in phosphoric acid technology. This explains an almost exclusive preference for the hemihydrate phosphoric acid process as compared to the dihydrate used on this continent.

TABLE IV

Guillini Process Operating Costs (1976)

Assumptions (1) 300 tons/day waste gypsum converted into dry hemihydrate powder from the dryer.  
(2) 300 days on-stream time annually  
(3) Investment costs \$1.3 MM

Unit		
L.P. Steam	0.5 tons	2.60
Hot Water	0.5 M <sup>3</sup>	1.37*
Raw Water	2 M <sup>3</sup>	3.66*
Electricity	35 kwh	.58
Natural Gas	200,000 kcal	1.30
Chemical Additive		.41
Labour	2 men @ \$15/hr	2.40
Transportation (200 miles)	per ton	7.00
Depreciation	14.3%	2.07
Maintenance	<u>7%</u>	<u>1.01</u>
Total Costs	ton	22.40

\*Includes \$8.33 per 1,000 gallons subsequent lime treatment costs

As shown in Table V, this results in sharply reduced impurity levels:

TABLE V

Comparision of Impurities in Calcium Sulfate from Hemihydrate and Dihydrate Phosphoric Acid Processes

	Nisson Hemihydrate	Prayon Dihydrate
CaO	31.8	32.1
SO <sub>3</sub>	45.3	45.1
Total P <sub>2</sub> O <sub>5</sub>	.22	1.07
Total F	.2	.8
Na <sub>2</sub> O	.1	.1
K <sub>2</sub> O	.03	.02
S <sub>1</sub> O <sub>2</sub>	.8	1.8

This results in relatively simple purification steps, which when correlated with improved plaster characteristics, (see Table VI), presents an entirely different picture than in North America:

TABLE VI

Hydration Properties of Calcined Phosphogypsum from Dihydrate and Hemihydrate Processes

Process	Additional Treatment	Amount of Mixing Water	Tensile Strength Kg/Cm <sup>2</sup>	Usability of Plaster
Dihydrate 1	none	63	3.5	Impossible
	neutralization	63	6.5	Difficult
Dihydrate 2	none	72	4.0	Impossible
	neutralization	72	8.5	Difficult
Hemihydrate- Dihydrate 1	none	75	11.0	Difficult
	neutralization	75	9.0	Favourable
Hemihydrate- Dihydrate	none	70	16.2	Favourable
	neutralization	70	15.0	Favourable

It should be noted that this situation could change in the not too distant future, as Hemihydrate processes have other advantages not related to calcium sulfate

characteristics. An important one is the production of a relatively concentrated form of phosphoric acid without the need for evaporation and a consequent significant reduction in energy costs. This factor will undoubtedly lead to serious consideration of hemihydrate technology when future phosphoric acid plants are built on this continent. This in turn, could lead to revised thinking on the utilization of by-product gypsum. The inevitable fly-in-the-ointment not investigated is the disposal of copious quantities of phosphate and fluoride-contaminated water from the gypsum recovery process.

The question of water disposal is of continuing concern to phosphate manufacturers. As discussed above, typical North American gypsum disposal practice is based on the use of gypsum ponds. At Courtright, we use two pairs of ponds, each pair involving one settling and one cooling pond. Gypsum slurry is pumped to the settling pond in use, from which clarified water is decanted to the associated cooling pond before being recycled for re-use in the phosphate plant. The ponds therefore act, not just as a gypsum disposal site, but also as a total recycle system for phosphate-contaminated water. This eliminates the problem of phosphate losses to the plant effluent and compensates for the admitted eyesore of the gypsum stacks.

Practice at CIL is to use one pair of ponds for about twelve months before switching to the disused set. Gypsum is then removed by dragline to build up the dykes surrounding the ponds. Pond water is grossly contaminated with sulfates, phosphates, fluorides, a typical analysis being as shown in Table VII. Consequently, dykes must be designed correctly to prevent the escape of contaminated water.

TABLE VII

Typical Analysis of Gypsum Pond Water

Phosphate	10,000 ppm	Sulfate	7,300
Fluoride	5,600	Sodium	1,700
Silica	2,000	Potassium	300
Calcium	700	pH	1.5

Effective management of gypsum ponds faces some formidable problems. One of the most severe is to maintain a favourable water balance. If rainfall plus make-up water from the phosphoric acid process exceeds natural evaporation from the ponds, an unfavourable water balance exists. If allowed to continue, a point is reached where excess water must be discharged. This must be chemically treated prior to release and typically involves adjusting pH from about 1.5 to 10.0 and settling the precipitated calcium phosphate and fluorides. In 1973 capital investment for such a treatment facility was estimated at \$350,000 and operating costs at \$3.50 per 1000 gallons. Consequently, there is a continuing effort in most land-locked phosphate plants to maintain a favourable water balance. Normal procedure is to base as many plant operations as possible on recycled pond water. Nevertheless, because of the contaminants, this proves impossible in some instances. One such instance is the dilution of 93% sulfuric used in the digestion of phosphate rock to the required 55 - 65%. As explained in the first page of this paper, the heat load in the digestion step of a phosphoric acid plant must be carefully controlled, and this is usually accomplished by cooling the diluted sulfuric acid and flash cooling the reaction slurry. Typically, both the dilution and cooling of the sulfuric acid are carried out in a water-cooled

carbon tube heat exchanger. If gypsum pond water is used to dilute the acid, calcium sulfate precipitates plugging the tubes; hence, the customary use of river water in this application. At Courtright, this represents a very significant 24,000,000 gallons of make-up water to the ponds.

It is apparent that if pond water is to be used in this dilution, the calcium ions must either be removed or their solubility increased. Numerous experiments with ion exchange to remove calcium proved unsuccessful, but eventually an ingenious solution was developed in the CIL Research Laboratories. At school, we learned that if a common ion is added to the solution of a sparingly soluble salt, the salt would precipitate. In fact, this is not necessarily so. If the addition of a common ion is continued a point is often reached where the solubility increases. The underlying theory is that as the ionic strength of solutions increases, the activity decreases. For example, if the solubility equilibrium of the relationship ---

$$(C_{M+} + C_{A-}) (f_{M+} + f_{A-}) = \text{constant}$$

is to be maintained, a point is reached in the addition of a common ion, where the solubility of  $C_{M+}$  (assuming the added ion is  $C_{A-}$ ) must increase. In our case, we discovered that if the sulfuric acid was diluted to 70% rather than 63, the precipitation of calcium sulfate could be delayed long enough to prevent precipitation in the Karbate tubes. Fortunately, we were able to compensate for the marginal increase in heat load elsewhere in the process. We have used this since-patented technique for several years. Not only does the process contribute effectively to a favourable water balance, it also recovered some 1,500 tons of phosphoric acid annually from the gypsum ponds.

This fourth example concludes my presentation. If past trends continue, it appears almost inevitable that changes in environmental legislation and the increasing scarcity and costs of raw materials will focus our attention

increasingly on the recovery of 'waste' streams. Based on our experience to date, this challenge can be met with innovation and skill, which in addition to solving a social problem can often result in a financial savings to a company. We trust the information provided in this discussion will be of value to others facing similar problems.

\*\*\*\*\*

FIGURE 1

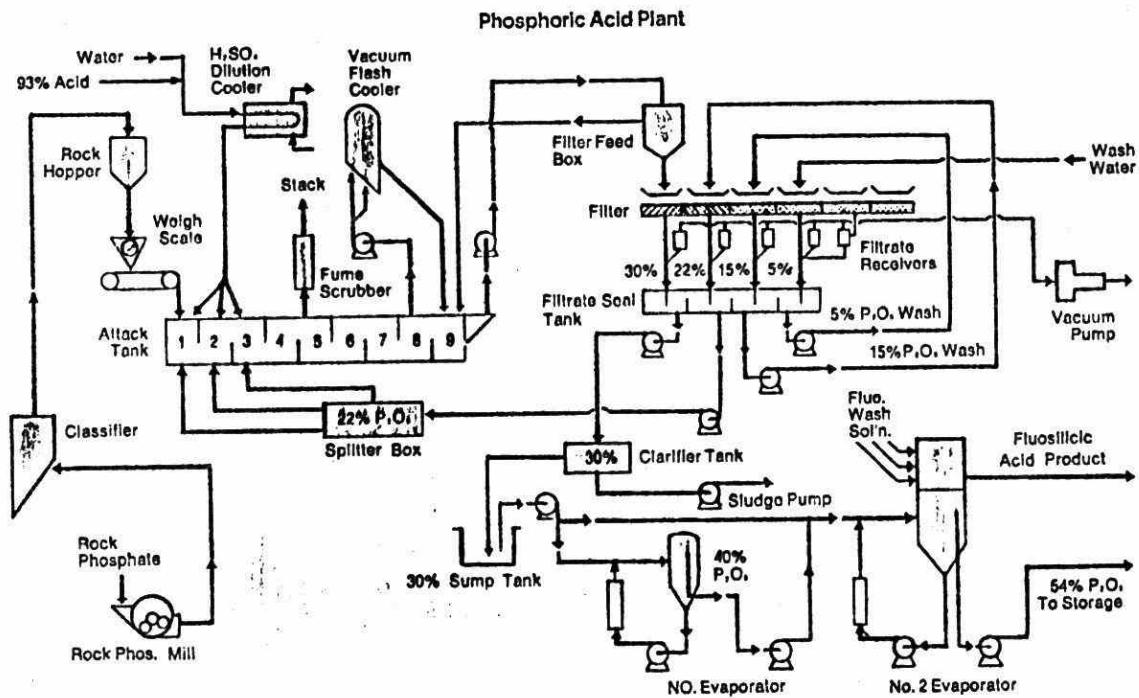


FIGURE 2

ALKYLATION WASTE ACID PLANT

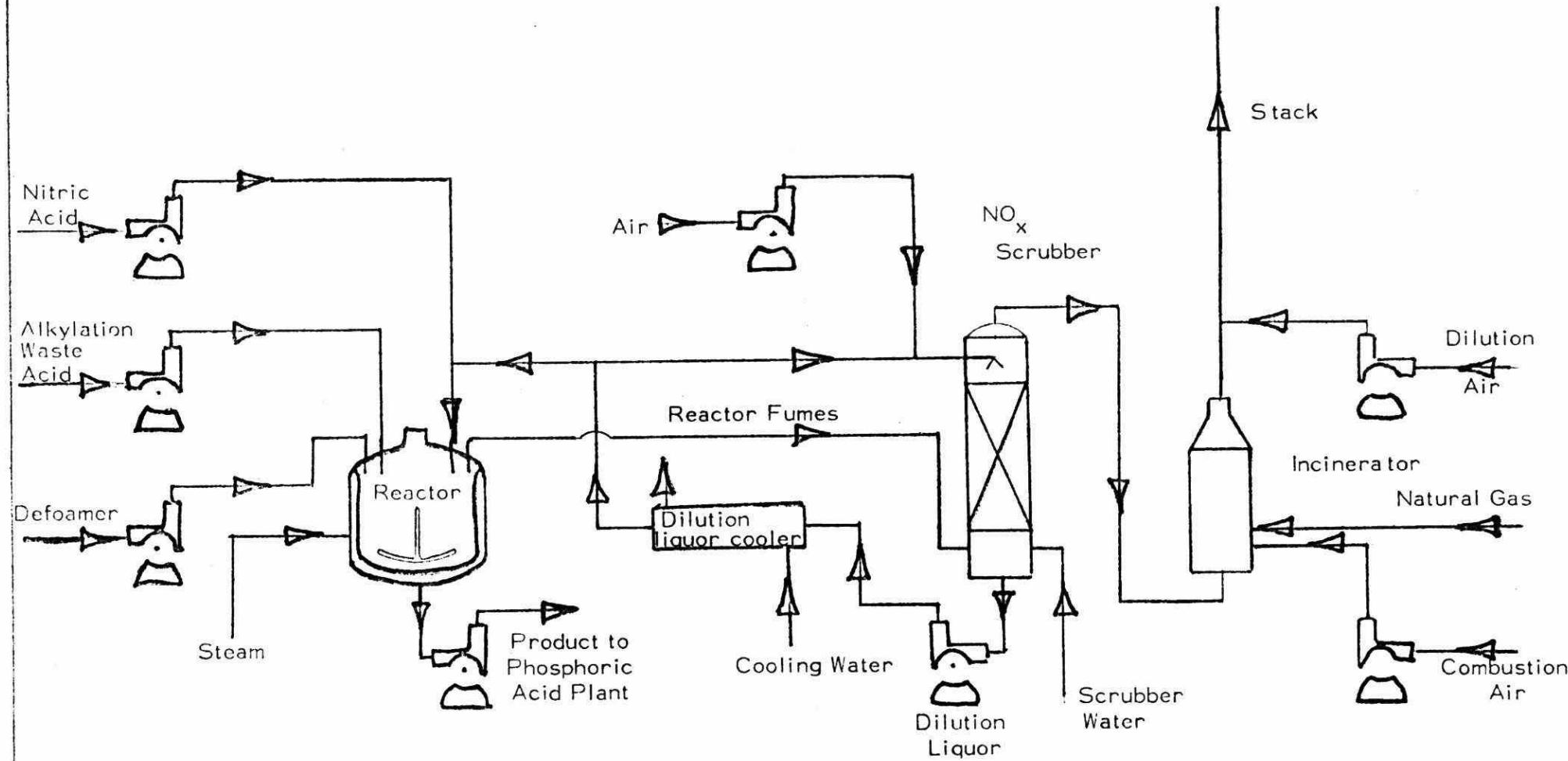


FIGURE 3

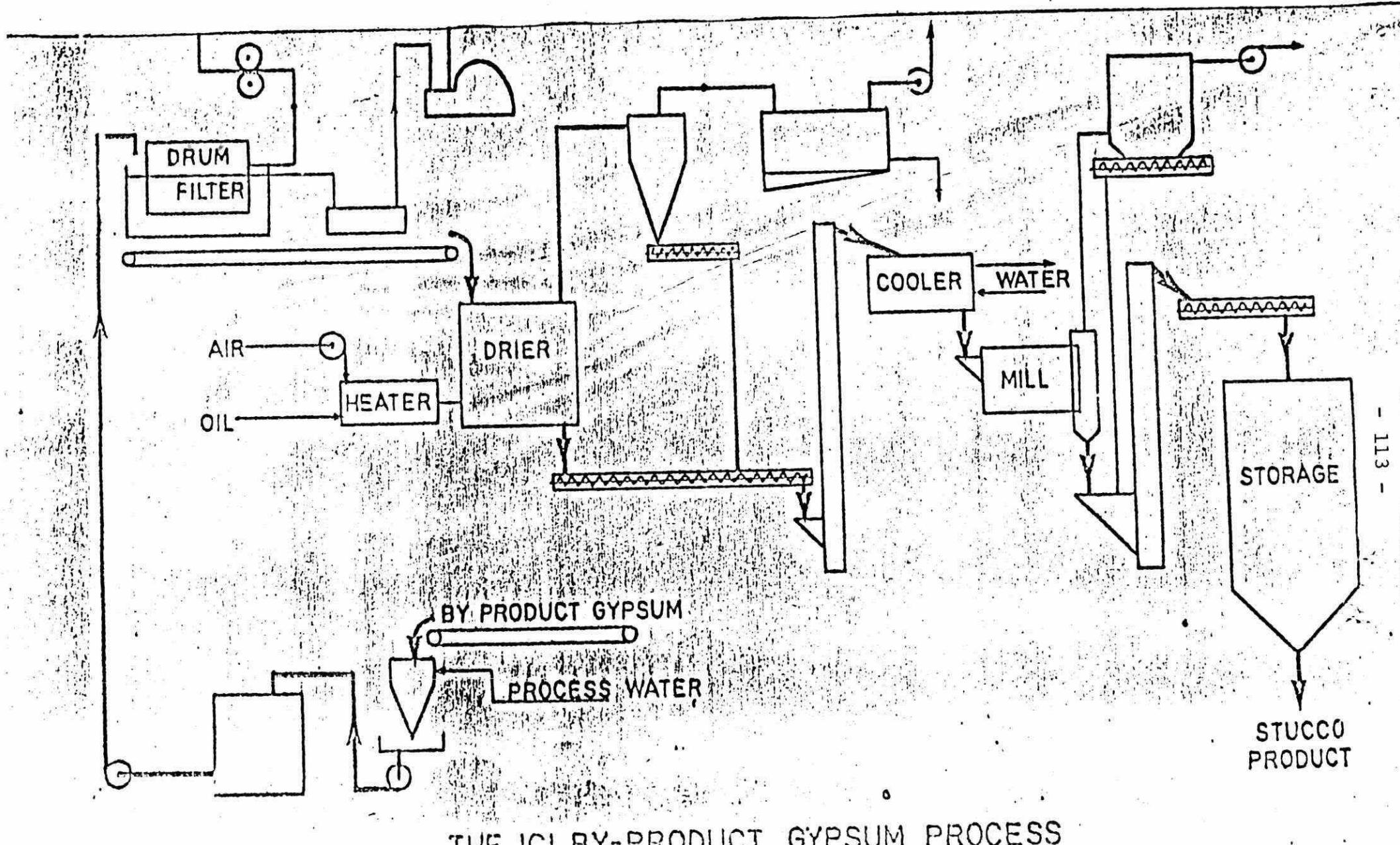
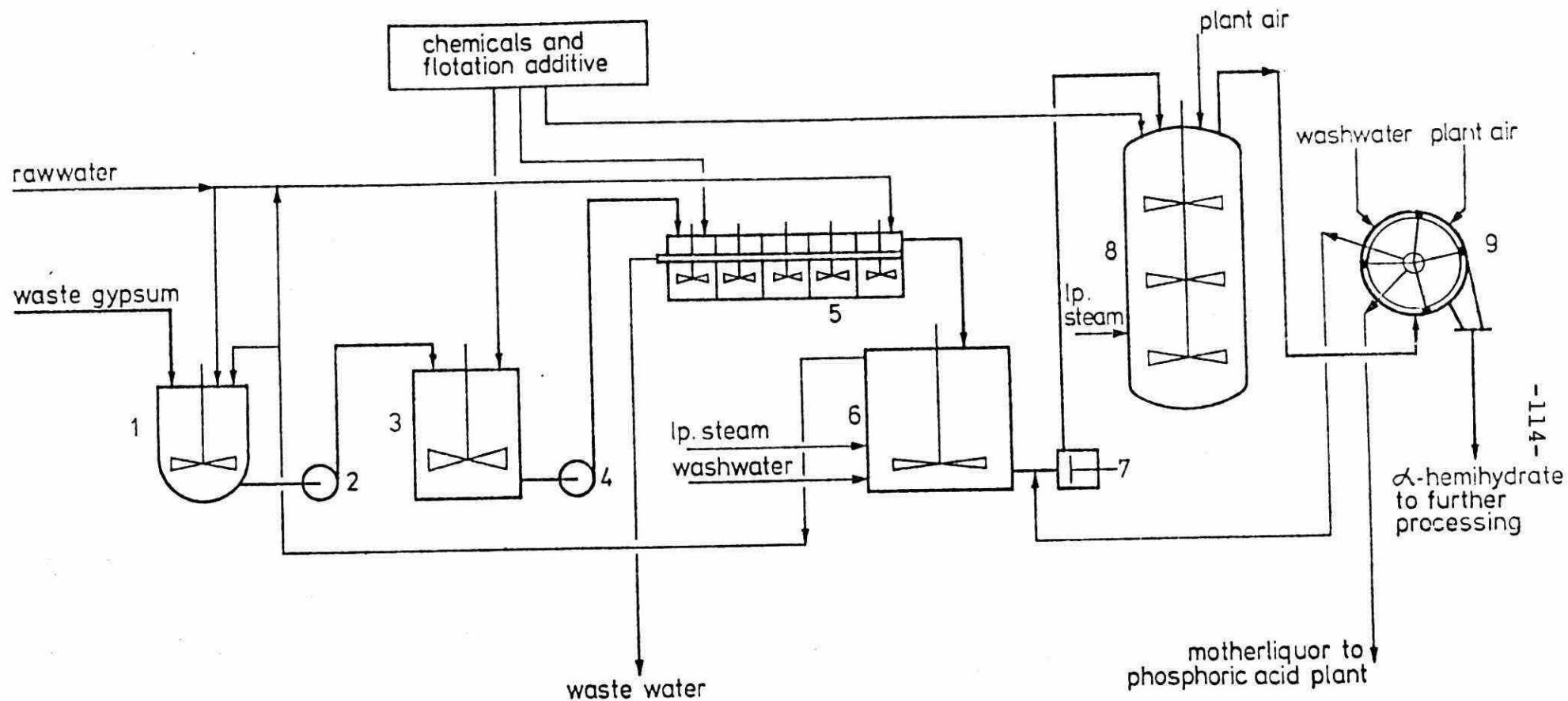


FIGURE 4 - GUILINI GYPSUM RECOVERY PROCESS



1	MIXING VESSEL	6	THICKENER
2	CENTRIFUGAL PUMP	7	METERING PUMP
3	BUFFERTANK	8	AUTOCLAVE
4	CENTRIFUGAL PUMP	9	PRESSURE FILTER
5	FLOTATION MACHINE		

THE UTILIZATION OF SPENT CAUSTIC

By

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For Presentation at a Seminar  
on Utilization of Mining & Industrial Waste  
Queens Park, Toronto, Ontario  
October 13, 1977

## The Utilization of Spent Caustic

### A Case History Presented By Esso Chemical Canada

#### Introduction

For many years caustic soda in dilute solution has been widely used in oil refining & petrochemical industries as a treating agent for the removal of sulphur compounds, carbon dioxide and phenols from intermediate and product streams. Although technology has been developed to remove the bulk of these impurities by other means, caustic treating is still the most economical method of reducing final traces to specification limits.

At Esso Chemical's Sarnia plant, where ethylene is produced from the cracking of petroleum feedstocks, caustic is utilized to a substantial degree to ensure the purity of the final product for downstream customers. A continuous withdrawal and makeup system is employed which results in an accumulation of spent caustic, amounting to approximately 200 barrels or 40 tons/day. This material is still highly caustic and considerably odorous. It does not lend itself readily to regeneration and must be disposed of to the satisfaction of the Ministry of the Environment. This means, of course, that discharge to watercourses or liquid land fill areas is taboo.

#### Disposal Methods

For several years the spent caustic was diluted with other liquid wastes and pumped down disposal wells into a porous sub-surface strata some 600 to 800 feet below. Unfortunately, the existence of old, uncharted wells drilled into the same strata during the early years of oil exploration, and the consequent fear of possible contamination of water wells in the surrounding farming area, caused the Ministry to force abandonment of this means of disposal.

Various alternates were explored, all of which proved either prohibitively expensive or not a complete solution to the problem. These included the use of catalytic agents to more fully utilize the caustic and reduce volumes for disposal, unproven regeneration processes, oxidation, fluid bed incineration and neutralization with sulphuric acid or carbon dioxide.

Faced with the necessity of finding an acceptable solution within a years time, we explored the possibility of shipping the spent caustic to Kraft Pulp Mills for reuse. Here was an industry which was known to utilize solutions of caustic soda and sodium sulphide in considerable quantity and appeared to be ideally suited as an outlet provided our material, which contained essentially the same chemicals, was acceptable and economical. (See Table I)

#### Chemical Utilization at Kraft Pulp Mills

The Kraft process depends on cooking wood chips at elevated temperatures in a liquor containing 2/3s sodium hydroxide and 1/3 sodium sulphide. These chemicals react with the lignin in the wood, allowing the cellulose fibres to be liberated.

The economics of the process requires recovery of the residual chemicals in the spent cooking liquor. This "weak black liquor" is subjected to an elaborate recovery process involving oxidation, evaporation, and burning to remove organic matter. The resultant molten salts are dissolved to form a "green liquor" containing sodium carbonate and sodium sulphide. Lime is added to convert the carbonate to sodium hydroxide. Insoluble calcium carbonate produced in the reaction is precipitated and removed. The clarified solution, containing the two major cooking chemicals is known as "white liquor" and is ready for reuse in the digester. This process is shown schematically in Figure I.

Loss of caustic and sulphur compounds is inherent in the cycle and make-up is required. Most Kraft Mills require about 100 to 160 pounds of sodium sulphate per ton of pulp as make-up, depending on the recovery efficiency. This is added to the black liquor for subsequent reduction to sodium sulphide.

### Utilization of Spent Caustic as Make-up

In 1972, visits to different mills were arranged to discuss the possible application of spent caustic as chemical make-up. It turned out that the mills were quite interested, particularly since the laid down cost of sodium sulphate was rising.

Test shipments were subsequently arranged and were found to be acceptable in quality, and compatible with their own white liquor. There followed a period of negotiations and contracts were eventually formulated to our mutual satisfaction. Since we were interested primarily in disposal, pricing formulas were easily negotiated.

All was not accomplished without cost, however. At the Chemical Plant, it was necessary to install adequate facilities for storage and shipment. Several tank cars had to be leased to ensure continuity of shipments, and Laboratory testing of each shipment was required to ensure that the material met specifications.

The specifications included a limitation on particulate material such as iron sulphide, and an absence of hydrocarbon. In order to meet these it was necessary to develop and install filtration facilities. A novel bed filter was developed employing a proprietary medium which absorbs any hydrocarbon and reduces particulates to required limits. The author was granted a patent on this application, which has been assigned to Esso Chemical.

### Conclusion

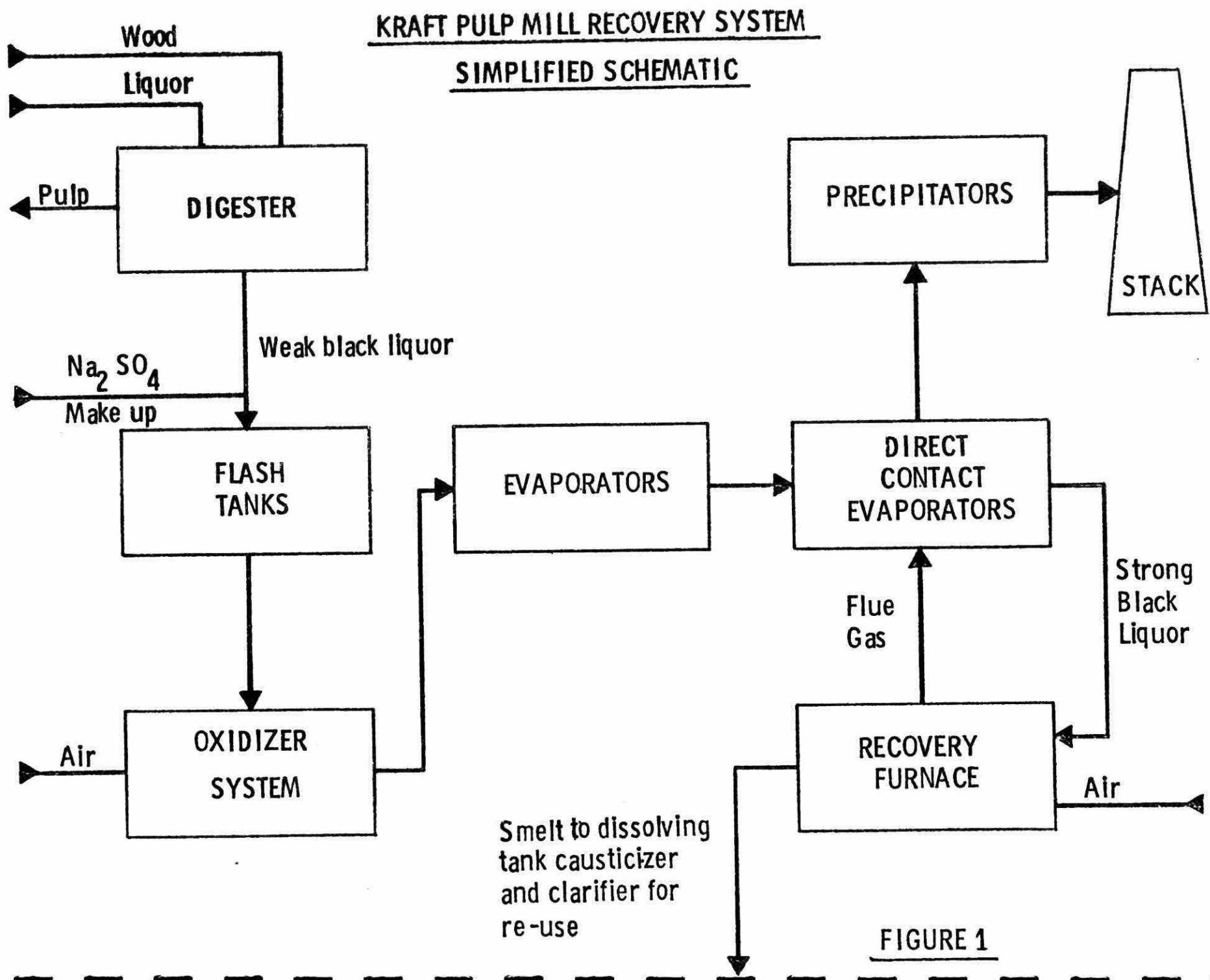
Pulp mills have been receiving all of our spent caustic production since 1972. By establishing outlets at several mills we have been able to avoid interruptions due to shutdowns, labor problems and the like. We have not only solved a very difficult disposal problem but established a renewable resource which is benefiting the Pulp Mill industry.

TABLE 1  
PROPERTIES OF SPENT CAUSTIC VS  
PULP MILL REQUIREMENTS

	<u>TYPICAL SPENT CAUSTIC</u>	<u>PULP MILL REQUIREMENT</u>
BEAUME GRAVITY	200	180 MIN.
ACTIVE ALKALI LBS. Na <sub>2</sub> O/CU.FT.	8-10	6.8 MIN.
% SULPHIDITY	15-25	15-30
Na <sub>2</sub> S, WT. %	0.65	NOT SPECIFIED
NaOH WT. %	13.3	NOT SPECIFIED
Na <sub>2</sub> CO <sub>3</sub> WT. %	0.9	NOT SPECIFIED

ACTIVE ALKALI = Na<sub>2</sub>S + NaOH EXPRESSED AS LBS. Na<sub>2</sub>O/CU.FT

% SULPHIDITY =  $\frac{\text{Na}_2\text{S}}{\text{ACTIVE ALKALI}} \times 100$



RYE ON ROCKS

Short film on the reclaiming of land used  
for the disposal of tailings. Courtesy  
of International Nickel Company of Canada  
Ltd.

THE UTILISATION OF MINING, METALLURGICAL AND INDUSTRIAL  
WASTES AND BY-PRODUCTS IN WESTERN EUROPE

by

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ABSTRACT

This Paper considers the uses which have been found for the many waste materials and by-products produced in Western Europe. It concludes that the vast majority of these materials are of limited interest either because their potential uses are few or due to their occurrence in only one or two countries. However, three materials - colliery spoil, blast-furnace slag and fly ash - are of widespread occurrence and have many uses. The quantities that occur, their properties and the uses that have been found for them in road and building construction, cement manufacture and land reclamation are therefore considered in more detail.

INTRODUCTION

The advantages in terms of environmental benefits, resource conservation and savings in energy, of using waste materials and by-products in place of traditional materials in road and building construction are well-known. There are, of course, many limitations which explains why they are not as widely used as many would wish. These advantages and disadvantages have been fully discussed in several publications (eg References 1, 2 and 3) and it is not the purpose of this paper to discuss them in any detail. Instead it is proposed to discuss, with particular reference to Western Europe, the uses which have been made of some of the major wastes and by-products that occur widely in most industrialised countries.

#### MATERIALS OF PRIMARY INTEREST

The waste materials and by-products that are available in some countries that are members of the Organisation for Economic Co-operation and Development (OECD) and the uses made of them in road construction are the subjects of a report to be published in the near future<sup>1</sup>. In this publication more than 30 waste materials and by-products were identified as having some potential uses in road construction. It does not deal in any detail with their uses outside the field of road construction so that it is clear that a full review of their use in both roads and building construction and for land reclamation would be a lengthy publication which could not possibly be condensed into a short paper; nor would this serve a particularly useful purpose as many of the materials are of limited potential and in some cases occur only in one country.

However, from the OECD report it is possible to select three wastes and by-products which are of widespread occurrence in many countries and which have great potential for use in all forms of construction. These materials - colliery spoil, blast-furnace slag and fly ash - which are respectively examples of mining, metallurgical and industrial wastes have therefore been chosen to illustrate in the space available the many uses which have been found for waste materials and by-products in Western Europe.

#### COLLIERY SPOIL

Colliery spoil deposits are composed of the waste products from coal mining which are either removed to gain and maintain access to the coal faces or unavoidably brought out of the pit with the coal and have to be separated out at the coal-cleaning plant. Wastes from both sources are usually dumped on the same spoil heaps together with small quantities of coal and other washings so that the heaps are very variable in composition. Superimposed on this variation is an additional one arising from combustion in the heaps. When this occurs the physical and chemical composition is changed so that the burnt spoil differs considerably in its properties from the unburnt material. Production figures for colliery spoil are given in Table 1.

TABLE 1

Annual production of colliery spoil in Western Europe and North America  
(Quantities in million metric tonnes)

Belgium	4
France	20
Great Britain	56
West Germany	60
Netherlands	0.3
Canada	5
United States	90

Source: OECD<sup>1</sup>

Apart from the quantities given in Table 1 all producing countries have large stockpiles of colliery spoil arising from production in the past. For example, in England and Wales there are 3000 million tonnes available which are deposited in tips occupying about 150 sq km (60 sq miles)<sup>4</sup> of land. The sterilisation of land by these tips and their usually unsightly appearance is one of the pressures leading to demands for finding beneficial uses for the material. However, in Great Britain it is recognised that it is most improbable that it will ever be possible to use all the material that is available. Many tips are therefore re-contoured and planted with trees so that they blend into the landscape and are no longer visually obtrusive.

Properties of colliery spoil (shale)

Unburnt and burnt colliery spoil are strikingly different in their physical and chemical properties. The most obvious difference between them is the change in colour from grey-black to red-brown. The burning process leads to a reduction in the proportion of combustible matter, to the partial or complete decomposition of the clay minerals and carbonates and to the oxidation of the sulphides to soluble sulphates<sup>4</sup>. The composition of both unburnt and burnt material even from the same heap is very variable and heaps that are classified as burnt are often only partially burnt. The chemical composition of some burnt and unburnt colliery spoil is given in Table 2.

Chemical analysis of burnt and unburnt British colliery spoil<sup>5</sup>  
(in weight per cent)

	Burnt spoils from colliery:						Unburnt d
	A	B	C	D	E	F	
SiO <sub>2</sub>	57.6	56.2	60.2	55.6	56.4	45.4	51.9
Al <sub>2</sub> O <sub>3</sub>	31.3	31.1	21.2	26.5	23.3	21.5	19.4
Fe <sub>2</sub> O <sub>3</sub>	3.86	4.33	8.02	4.57	6.14	13.37	6.1
TiO <sub>2</sub>	0.22	0.24	0.17	0.22	0.22	0.22	1.03
CaO	0.36	1.03	0.44	0.16	0.48	6.30	0.66
MgO	0.92	0.82	1.01	1.47	0.97	2.88	1.21
Na <sub>2</sub> O	0.23	0.20	0.48	0.23	0.44	0.65	0.44
K <sub>2</sub> O	2.50	2.06	3.30	3.45	2.63	2.77	3.0
SO <sub>3</sub>	0.10	1.39	0.89	1.86	2.82	4.66	0.35
S	0.20	0.01	0.10	0.02	0.10	0.05	0.02
loss on ignition	1.9	2.2	3.8	6.3	5.5	2.6	16.13
TOTAL	99.0	99.6	99.6	100.4	99.0	99.8	100.4
pH of spoil-water suspensions	6.5	6.8	5.4	4.2	4.5	8.5	Not determined
Sulphate content of 1:1 spoil-water suspensions (% as SO <sub>3</sub> )	0.06	0.14	0.16	0.70	0.69	0.15	Not determined

Uses of burnt colliery spoil

The combustion of colliery spoil produces a stable granular material that can be used as an aggregate in place of naturally occurring aggregates. The principal use for the burnt material is as an unbound granular sub-base material for road construction. Material of suitable grading for this purpose is readily obtained (Fig 1). The two major problems likely to be encountered are frost susceptibility and the presence of soluble sulphates that may attack concrete structures in the vicinity of the material. British specifications<sup>6</sup> allow for this by requiring all

materials to satisfy conditions for frost susceptibility and sulphate content. Frost-susceptible materials that fail to meet the frost-heave requirement may not be used within 450 mm of the road surface and materials with high soluble-sulphate contents are not permitted to be used within 500 mm of concrete structures.

The risk of sulphate attack of concrete also limits the use of burnt colliery spoil as a concrete aggregate and as a fill material under buildings. The lifting of concrete floors in buildings due to sulphate attack when burnt spoil has been used as fill has caused serious problems. A maximum sulphate content of 0.5 per cent is therefore recommended in Britain when burnt spoil is used as an underfloor fill and as an extra precaution a waterproof barrier between the fill and the concrete is recommended<sup>7</sup>.

#### Uses of unburnt colliery spoil

The major outlet for unburnt colliery spoil at present is as bulk fill for earthworks in road construction but it is also used as the raw material in brick manufacture and in cement manufacture, for the production of artificial aggregates and in land reclamation.

As bulk fill in road construction. Large quantities of unburnt spoil have been used for bulk fill particularly in Great Britain and Germany where specifications have been prepared covering its use for this purpose<sup>6, 8</sup>. The fear that spontaneous combustion may occur if unburnt spoil is used has been the major restriction on its use but the risk that it may occur in a road embankment has been found to be greatly exaggerated. Spontaneous combustion in the material is determined not only by the carbon content but also by the particle size, the distribution of carbonaceous material present, the pyrites (iron sulphide) content, the proportion of volatile constituents in the carbonaceous material and in particular the possibility of oxygen penetrating into and through the embankment. For these reasons no limits can be given for the permissible amounts of carbonaceous material. Experience has shown that spontaneous heating does not occur if embankments are well compacted.

In recent years about 6 million tonnes/year of unburnt spoil have been used in Great Britain for embankment construction. The major limitation is availability as it is rarely economic to transport it to areas more than about 10 km from the tip. There are, of course, environmental advantages to be gained from its use and these are also taken into account in deciding whether or not the material should be used.

In brick manufacture. About 500 000 tonnes/year of colliery spoil are used in Great Britain for brick manufacture<sup>9</sup>. The problems associated with using colliery spoil are the variability of its composition especially the carbon content, the effluent problem and the soluble salts present in the fired product<sup>4</sup>. Production of bricks from colliery spoil is on the decline because surface clays are more readily accessible, easier to handle and process, and give a better product.

In cement manufacture. The two main components for the feedstock for cement making are calcium carbonate rocks and argillaceous rocks. Cement works are therefore generally site where supplies of both, usually from surface quarries, can be readily obtained. Colliery spoil can be used to supply the argillaceous component and one British cement works which has no convenient alternative supply uses about 130 000 tonnes/year<sup>9</sup>.

For the manufacture of artificial aggregates. Expanded light-weight aggregate has been produced commercially in several countries by the sintering of unburnt colliery spoil. Colliery spoil has a marked advantage over many others used for the manufacture of artificial aggregates in that it contains within itself sufficient carbon to sustain any sintering process required. The main problems are the variability of the material particularly in the fuel content and air pollution by the gases driven off during combustion.

A good example of how an attempt to solve one problem can create another is offered by the recent experience of a plant set up in S E England to produce aggregate from locally available spoil. This was in an area where natural aggregates are in short supply and the presence of spoil tips is particularly incongruous in an otherwise attractive countryside. The environmental advantages of producing aggregate from colliery spoil seemed to be considerable and it is therefore ironic that as soon as production started there were demands that the plant should be closed down on the grounds that it was causing excessive air pollution.

Although light-weight aggregates offer a clear advantage in certain circumstances, the demand for them is limited and in many instances dense aggregates are preferable. Because of this, research has been done in Britain to find means of producing dense aggregates from colliery spoil and a process for doing this has been patented<sup>10</sup>.

For land reclamation. Colliery spoil has been used for dike construction to raise river embankments in Germany<sup>11</sup> and the material has been exported from Germany to Holland for land reclamation schemes on the Dutch coastline. It has also been considered for use for large-scale reclamation in Britain but the costs of transporting it have proved too high. For example proposals were made to move 400 million tonnes

at an estimated cost of £600 million to reclaim land needed for the construction of the third airport for London off the coast of Essex<sup>12</sup>. However, as it was calculated that this would be more expensive than dredging sand from off-shore the proposal was not pursued. In the event the whole concept of the airport was abandoned.

#### BLAST-FURNACE SLAG

Blast-furnace slag is produced as the by-product of iron-making and results from the fusion of limestone with the siliceous and aluminous residues remaining in the blast furnace after the iron has been separated from the ore. The amounts produced in different countries depend not only on their iron production but also on the quality of the ore so that the amount of slag produced per tonne of iron may vary from 200 kg to 1200 kg. The slag produced may take the following forms depending on the treatment it is given after leaving the blast furnace:

Air-cooled slag is produced when the molten slag is allowed to cool slowly in air. This produced a crystalline product which may be readily crushed and used as an aggregate.

Granulated slag is produced when the molten slag is cooled rapidly by means of high-pressure water jets. Crystallisation does not occur and the material solidifies to give a vitrified product.

Pelletised slag is a fairly recent innovation and is produced when the molten slag is rapidly cooled in air.

Foamed or expanded slag is formed when the molten slag is discharged rapidly into a pond in the bottom and sides of which are water jets. The object is to generate steam inside the slag.

The amounts produced of the different types of slag in some OECD member countries are given in Table 3.

TABLE 3

Annual production of blast-furnace slag in Western Europe and North America  
(Quantities in million metric tonnes)

	Air-cooled	Granulated	Pelletised	Expanded
Belgium	0.6	4.3	-	-
Finland	0.2	0.25	-	-
France	5	8	Started 1975	Small quantity
Great Britain	7	0.1	Started 1976	0.2
West Germany	9	3.4	-	-
Italy	0.5	3.2	-	-
Netherlands	0.15	1.2	-	-
Canada	2.2	-	0.2	-
United States	25	2	Started 1976	2

Source OECD<sup>1</sup>

Uses of slag

The different countries and the various types of slag produced combine together to give a wide range of uses which are summarised in Table 4.

The wide diversity of uses found for blast-furnace slag as illustrated in Table 4 has meant that in most countries slag is in great demand and unlike most other waste materials and by-products there is no disposal problem. Table 3 shows that present production in Western Europe is fairly evenly divided between air-cooled slag and granulated slag with pelletised and expanded slag playing very minor roles. It is interesting to compare Belgium, France and Italy where granulated slag is produced in preference to air-cooled slag with Britain, Canada and the USA where the position is reversed. The use of air-cooled slag in the construction industries is well-known and well-documented. For English-speaking countries it is therefore of more relevance to examine the possibilities of using granulated slag to see if it offers advantages that have been overlooked and whether it might be better to divert supplies from one use to another.

TABLE 4  
Uses of blast-furnace slag

Outlet	Type of slag used	Use
Cement manufacture - interground - separate grinding	Granulated, ground (ground pelletised)	- Cements with a slag content varying between 5 and 85 per cent
Highway pavements	Granulated	- Road bases - Stabilization of crushed natural materials
	Crushed air-cooled	- Aggregates for bituminous mixtures and pavement courses
	Mixtures of crushed, air cooled and granulated slag	- Pavement courses
	Mixtures of granulated or crushed, air-cooled slag and steel slag	- Pavement courses
Hydraulic concretes	Granulated (crushed)	- Sands for concretes - Mixtures of granulated slags and fly ash
	Crushed air-cooled	- Coarse aggregates and chippings
	Expanded (crushed)	- Aggregates for light insulating concretes
Railways	Crushed air-cooled	- Graded for use as ballast
Miscellaneous	Ungraded crushed air-cooled	- Embankments
	Graded crushed air-cooled	- Drainage blankets
	Fibrous	- Wool for insulation
	Granulated	- Sand for blasting - Scouring baked clays

Use in cement manufacture. Slag may be used in place of clay as the raw material for Portland cement manufacture but it is more usual to add it at the grinding stage to cement clinker to produce Portland blast-furnace cement. Most countries in Western Europe use it in this way; in France about 3 million tonnes/year are used and considerable amounts are also used in Germany, Belgium and Italy. The slag must, of course, fulfil certain requirements relating to its physical and chemical composition and in those countries where it is used specifications relating to its use in cement manufacture have been prepared.

The amount of slag added to the clinker can vary from 5 to 85 per cent and though it is usual to grind the Portland cement clinker and the slag together they may be separately ground and subsequently mixed. A further extension of this is to add ground granulated slag to cement when mixing concrete in construction sites and in Britain 60 000 tonnes/year of ground granulated slag are sold for this purpose under the trade name of "Cemsave".

The main advantage of using slag as an additive to Portland cement clinker lies in the savings in energy that can result from its use. The production of slag involves a high energy input and the energy fortuitously invested in its production can be utilised when it is added to cement. Thus it has been estimated<sup>13</sup> that for a Portland blast-furnace cement containing 65 per cent of granulated slag the expected energy saving is about 75 per cent of that required to produce the same amount of Portland cement; this works out at about 6 per cent of total production costs.

Portland blast-furnace cement can be used in place of Portland cement for most purposes. The rate of hardening is somewhat slower than that of Portland cement during the first few weeks but after a year the strengths developed by the two cements under comparable conditions are much the same. The resistance of blast-furnace cement to chemical attack is rather better than that of Portland cement.

Since in most countries no surplus slag is available the economic and environmental benefits that would result from diverting slag into cement production have to be weighted against the effect that this would have on the existing uses of slag. This is a fairly complex exercise which is outside the scope of this paper; an appraisal of the effect in Britain has been made by Smith<sup>13</sup>.

Slag as a hydraulic binder. Apart from its use in cement manufacture the cementitious properties of blast-furnace slag have been developed in France for sub-base and base construction in roads. Many countries throughout the world use cement and/or lime to stabilize sub-base and base materials. The French gravel-slag (grave-laitier) process is an extension of this concept in which granulated slag is used as the stabilizing agent for gravels and sands.

Granulated slag does not possess any hydraulic properties until it is activated. In the gravel-slag process this activation is achieved by small additions of lime or sodium carbonate. The reactivity of the slag varies between works and is measured by a so-called alpha ( $\alpha$ ) coefficient\*.

On the basis of this coefficient granulated slags are divided into four classes:-

Class 1: $\alpha < 20$	not used for road construction
Class 2: $\alpha 20-40$	the most frequently used
Class 3: $\alpha 40-60$	reserved for materials that are difficult to handle
Class 4: $\alpha > 60$	used only exceptionally

In France gravel-slag is produced in mixing plants; it consists of a mixture of gravel with 15 to 20 per cent granulated slag together with 1 per cent of hydrated lime (as the activator) and a moisture content of 10 per cent. The strengths obtained from gravel-slag mixtures are only about half those that would be obtained if Portland cement were used as the stabilizing agent. However, granulated slag is much cheaper than cement and gravel-slag has considerable advantages over cement-stabilized gravel as a construction material which may be enumerated as follows:-

---

\* The coefficient is defined as  $\alpha = S \times P \times 10^{-3}$

where S represents the Blaine specific surface in  $\text{cm}^2/\text{g}$  of the natural fines in the granulated slag (<80 microns)

P represents the friability properties determined by mixing in a ball-mill 500g granulated slag with 1950g of porcelain beads (having a diameter of 18 to 20 mm) and subjecting the mix to 2000 revolutions at a rate of 50 revolutions/minute. Three tests are carried out and the factor P defined as a percentage finer than 80 microns is determined after sieving and washing.

- (a) The relatively large amount (15-20 per cent) of granulated slag that is added facilitates homogenous distribution of the slag. Part of the slag remains available to allow renewed setting to develop should failure occur (self-healing).
- (b) The mixture takes a relatively long time to set which allows several days' storage without difficulty and in case of heavy rain the mixture can be allowed to dry before it is compacted.
- (c) In frosty weather the setting process is halted but is resumed when normal temperatures are reached.

The success of the gravel-slag process in France has led to its adoption in Belgium, Italy and more recently in Hungary<sup>14</sup>.

#### FLY ASH

Most modern coal-burning power stations burn coal which has been pulverised to a fine powder. The pulverised coal when it is burned in a furnace produces a very fine ash which is carried out of the furnace with the flue gases. This fly ash accounts for about 75-85 per cent of the ash formed from burnt coal. The remaining coarser fraction of the ash falls to the bottom of the furnace where it sinters to form a coarse material known as furnace bottom ash.

The fly-ash is removed from the flue gases by mechanical and electrostatic precipitation and it can be supplied as a dry powder at this stage, or alternatively it is transported hydraulically to lagoons where it can be later reclaimed if required. Because of separation that occurs during sedimentation in the lagoons, lagoon ash is more variable and is generally coarser as furnace bottom ash is often mixed with it. Large quantities of fly-ash are available in those countries that rely on coal-fired power stations for their electricity supply. The amounts available in some countries of Western Europe and North America are given in Table 5

TABLE 5

Annual production of fly-ash and bottom-ash  
in Western Europe and North America  
(Quantities in million metric tonnes)

	Fly ash	Bottom ash
Denmark	0.25	Not known
Finland	0.25	0.1
France		No figures available
Great Britain*	7.5	2.5
West Germany	7.3	6.6
Canada	1.8	0.45
United States	36	17

Source OECD<sup>1</sup>

\* In Great Britain fly ash is usually known as pulverised-fuel ash (PFA)

Fly-ash is a valuable by-product with many potential uses (Table 6). Some of these are discussed below.

TABLE 6

Utilisation of fly-ash and furnace-bottom ash in Great Britain<sup>13</sup>  
 Annual production - about  $10 \times 10^6$  tonnes/year  
 Utilisation by the construction industries 1971-72

	Tonnes x $10^6$	Percentage of total production
Bulk fill in roadworks	3.6	36
Concrete blocks	1.2	12
Other precast concrete	0.07	0.6
Lightweight aggregate	0.24	2.4
Grouting	0.07	0.7
Cement manufacture	0.06	0.6
Fired clay bricks	0.03	0.3
Cement-stabilized in road works	0.05	0.5
Industrial filler	0.008	0.1
Concrete	0.015	0.2
Other civil engineering uses	0.04	0.4
Remainder mostly used for land reclamation	4.6	46
TOTAL	10.0	100

Properties of fly-ash

Freshly produced fly-ash is a fine powder ranging in colour from light brown to dark grey, the colour depending to a large extent on the amount of unburnt coal in the ash. Fig 2 gives the particle-size distributions of some British ashes; these show that they are predominantly silt size. For comparison the Figure also includes the particle-size distributions of two lagoon ashes which show the generally much coarser gradings of these ashes.

The range of chemical composition of fly ash is given in Table 7. Apart from the elements shown in Table 7 all ashes contain carbon; the amount present depends on the efficiency of combustion and may be above 10 per cent for ash from older-type power stations to below 2 per cent for the more modern stations. Most samples of fly ash possess pozzolanic properties, ie they have the property of combining with lime and water to form cementitious material. This property is utilised in many of the applications that have been found for fly-ash.

TABLE 7  
Chemical composition of fly-ash (from Reference 16)

	Typical (%)	Range (%)	
SiO <sub>2</sub>	48.0	45.0	- 51.0
Al <sub>2</sub> O <sub>3</sub>	27.0	24.0	- 32.0
Fe <sub>2</sub> O <sub>3</sub>	9.0	7.9	- 11.0
CaO	3.3	1.1	- 5.4
MgO	2.0	1.5	- 4.4
K <sub>2</sub> O	3.8	2.8	- 4.5
Na <sub>2</sub> O	1.2	0.9	- 1.7
TiO <sub>2</sub>	0.9	0.8	- 1.1
SO <sub>3</sub>	0.6	0.3	- 1.3
Cl	0.08	0.005	- 0.15

#### Uses of fly ash

If its use for land reclamation is excluded it has been estimated that on a world-wide basis the average amount of fly ash put to good use is no more than 17 per cent of total production. Table 6 shows that in Great Britain this figure is much higher (54 per cent); in France 74 per cent is utilised and 37 per cent of this amount is used in road construction<sup>17</sup>. Some of the uses which have been found for the material are described below.

Uses in roadworks The grading of fly ash would suggest that it was not particularly suitable as a bulk-fill material for earthwork construction. In fact it has been found to have many desirable properties and in Great Britain the biggest single outlet for the material is for earthwork construction. When compacted, fly ash has a low density compared with most other materials used for bulk fill (Table 8). This lightweight property is advantageous when fill material is required on highly compressible soils and fly ash is often specified in these situations.

TABLE 8

Maximum dry densities and optimum moisture contents for various materials  
Typical results of standard compaction tests:

Type of material	Maximum dry density		Optimum moisture content (%)
	(Mg/m <sup>3</sup> )	(lb/ft <sup>3</sup> )	
Gravel	2.07	129	9
Sand	1.94	121	11
Sandy-clay	1.84	115	14
Silty-clay	1.67	104	21
Heavy clay	1.55	97	28
Fly ash	1.28	80	25

Many ashes possess self-cementing properties when they are compacted (Fig 3). The result of this hardening, if it occurs, is that settlement within fly-ash fill is less than with other materials. Fig 3 shows that wide variations in self-cementing properties can occur; this is believed to be due to variations in the free-lime content and the pozzolanic activity of the ash.

Some ashes contain sufficient free lime for them to be used as cementitious materials on their own. In Southern France an ash is produced which can contain up to 25 per cent of free lime; gravel stabilised with 4 per cent of this ash has been widely used for road construction in the area of the power station<sup>18</sup>. Similar ashes occur in Poland and are used to stabilize gravel for sub-base and base construction. In 1973 50 000 tonnes of fly ash was used in this way and this is expected to increase to an annual amount of 600 000 tonnes<sup>17</sup>.

A similar effect can be obtained by adding lime to fly ash and using the lime-fly ash mixture as a stabilizing agent. Such mixtures are used in France for stabilizing sands and gravels<sup>17</sup>; the feasibility of using British ashes in the same way has been demonstrated on a laboratory scale but they have not been used in practice<sup>15</sup>.

Use with cement. The pozzolanic activity of fly ash means that when added to Portland cement it will react with the lime released when the cement hydrates to produce further cementitious material. The pozzolanic activity of fly ash is variable but, if it is sufficiently high, up to 20 per cent of fly ash may be added to Portland cement without affecting the long-term strength of concretes made with cement-fly-ash mixtures, although the initial strength may be somewhat reduced.

In France fly ash has been used as an additive to cement since 1952 and about 1 million tonnes/year is currently used for this purpose. Fly ash is also used as an additive to cement in Germany, and French and German standards relating to the use of fly ash as an additive to cement have been published. In both countries the ash is blended with the cement at the cement works and proposals have been made for this to be done in Britain<sup>13</sup>. At present cement works in Britain are operating under capacity so that there is no great incentive for cement manufacturers to use either fly ash or granulated slag. However, as already mentioned granulated slag is sold as an additive for cement to be mixed on site and an analogous product based on fly ash is also on the market.

Unlike blast-furnace slag, where the advantages of diverting the already fully-utilised supplies into cement production are not clear-cut, there is a surplus of fly ash available and using it with cement offers clear environmental and economic gains. It has been estimated<sup>19</sup> that each tonne of selected fly ash used as an additive to cement saves the production of one tonne of cement and hence saves:-

1.2 tonnes of limestone or chalk

0.3 tonnes of clay

700 MJ of energy

plus the cost of restitution of the land from which the minerals have been extracted.

For the manufacture of artificial aggregates. Furnace bottom ash is used as a lightweight aggregate in the manufacture of concrete blocks. Fly ash can also be converted to a lightweight aggregate and two plants in Britain manufacture a product under the brand name of "Lytag". This is used in the manufacture of lightweight concrete blocks. Good workability due to the shape of the aggregate and enhanced strength at later ages due to the pozzolanic nature of the fines are claimed for concrete made with this aggregate.

For land reclamation Fly ash is ideally suited as a fill material to reclaim derelict mineral workings. In chemical composition it is similar to soil and it can be readily transported not only by road or rail but also very conveniently by

pipeline. In Britain 1200 ha (3000 acres) of old mineral workings have been filled in with fly ash and returned to agricultural or industrial use<sup>20</sup>.

Since 1965 an ambitious scheme to reclaim worked-out brick pits in the Peterborough area has been in progress. In this reclamation project fly ash is brought by rail in pressurised rail tankers similar to those used for transporting bulk cement. Each tanker holds about 20 tonnes of ash, the ash train consists of 48 wagons and the unloading station can handle up to 10 trains/day. The wagons are emptied by compressed air and as the ash is forced out it is immediately mixed with water to form a slurry containing about 25 per cent of ash. The slurry is then pumped to the particular pit being filled and is discharged into a pit at several points around the perimeter so that a reasonably even surface is produced.

When the work started the estimated capacity of the site was 30m tonnes. By the time the filling operation has caught up with continuing clay excavation the capacity will have risen to 50m tonnes.

#### CONCLUSIONS

The examples quoted in this paper show that there are a large number of outlets for the use of waste materials and by-products. In the case of blast furnace slag the many uses that have been found for it and the fact that its properties can to some extent be controlled by the producers has led to its being fully utilised in most Western European countries. With most other materials variable properties and the cost of transport from the source of production to areas where they are needed limit their use. Even so the big discrepancies in utilisation between different countries show that the low utilisation of a given material can be as much a matter of conservatism as inherent unsuitability or non-availability.

#### ACKNOWLEDGEMENT

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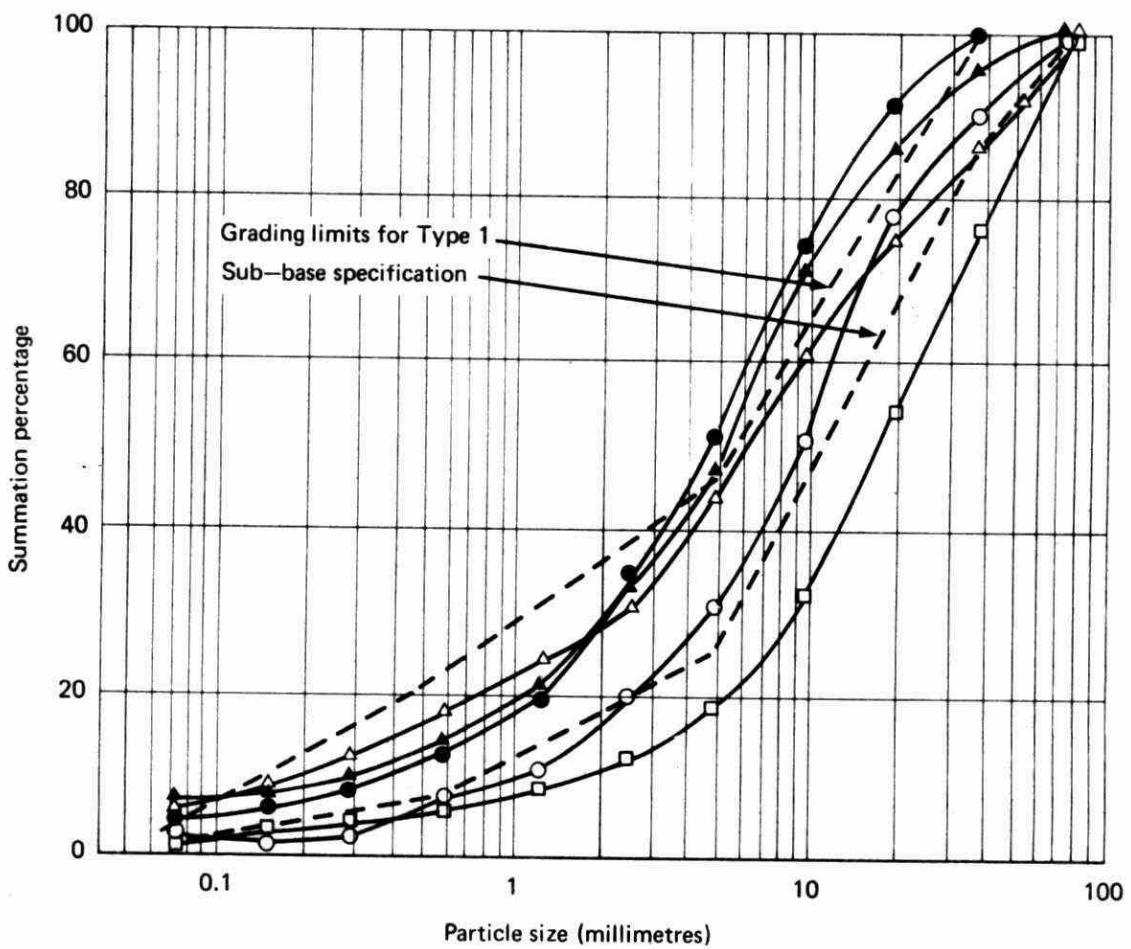


Fig. 1 PARTICLE-SIZE DISTRIBUTION OF SOME SAMPLES OF BURNT COLLIERY SHALE

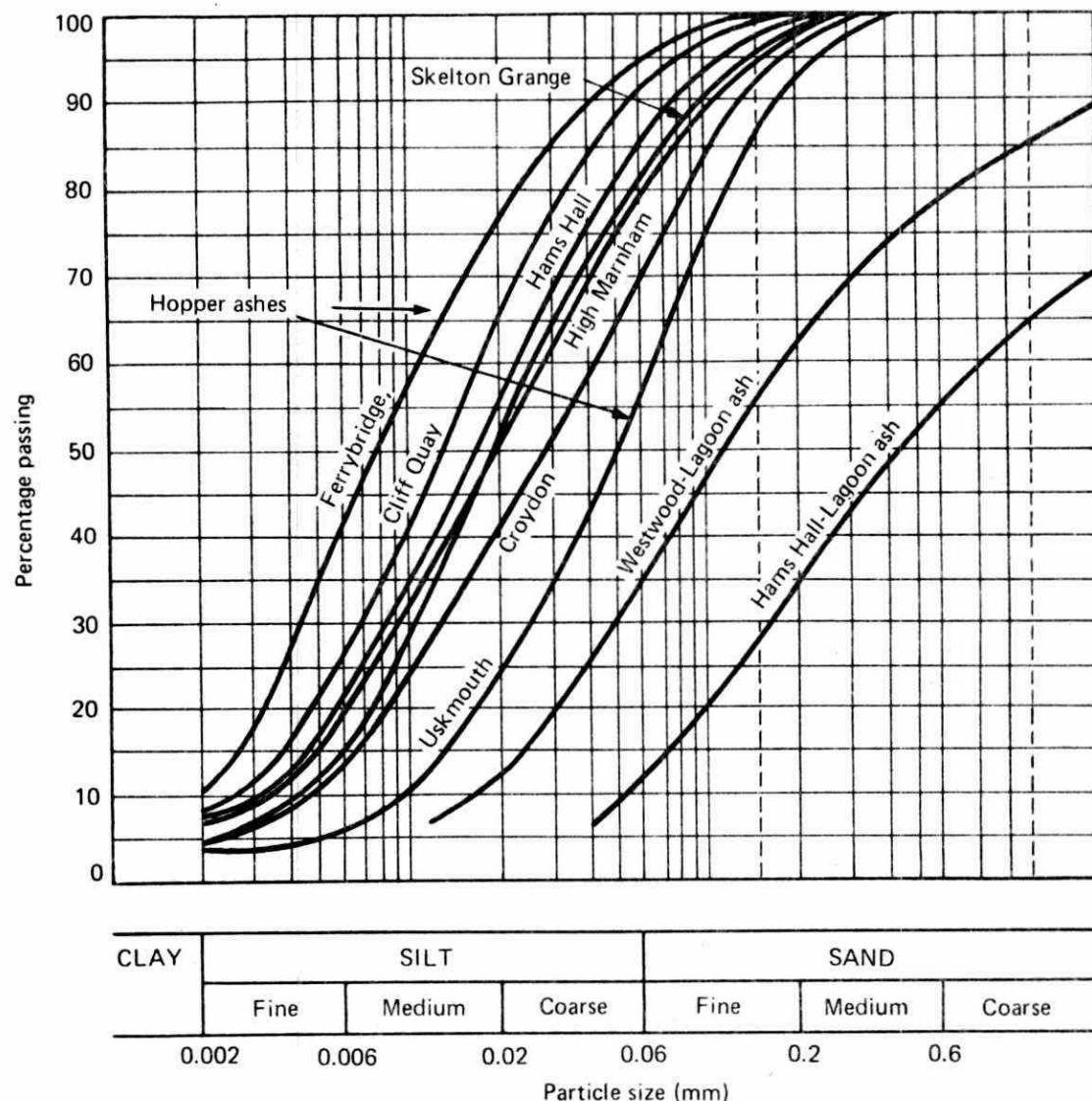


Fig. 2 PARTICLE-SIZE DISTRIBUTION OF SAMPLES OF FLY ASH

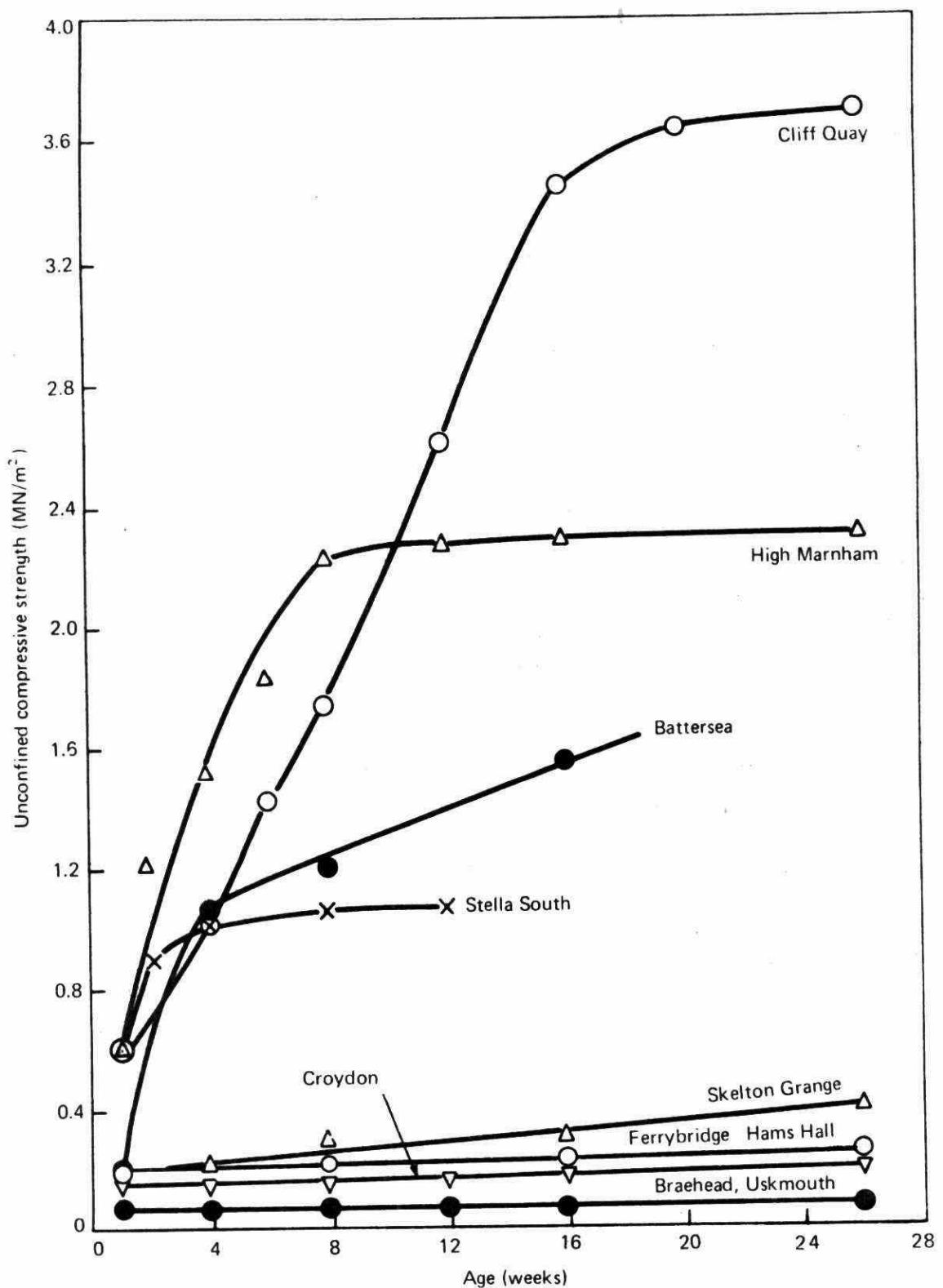


Fig. 3 STRENGTH-AGE RELATIONS OF SAMPLES OF FLY ASH

TODAY'S WASTE - TOMORROW'S RESOURCE

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Utilization of Mining and Industrial Waste  
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ABSTRACT:

A general review of the current and potential role of mining and quarrying, metallurgical, industrial, municipal, and agricultural and forestry wastes and byproducts as construction materials is given. While there is much developmental work completed, and the waste inventories are available, optimistic forecasts must be tempered by the technical and economic constraints that will tend to limit applications. The greatest potential is seen where energy is recovered or saved, or the waste or byproduct offers performance advantages. The most promising wastes and byproducts are indicated, and specific details are given on pelletized blast furnace slag, surplus sulphur and steel slags to illustrate the utilization concepts developed.

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### Introduction

"The elimination of waste", I explained, "by the utilization of all byproducts before they have time to go by, is the central principle of modern industrial organization."

Stephen Leacock

While the recycling of quotations is considered more plagiarism in literary circles, "Leacock's principle" recently cited by Brooks in Conservation in Canada [1] \* is so central to the theme of this seminar that its utilization here may even be encouraged. Following the often unproductive spurt of materials conservation activity triggered by the 1974 fourfold rise in petroleum prices, steady progress is now being made as the close interaction of energy, materials and environment is recognized, and measures adopted to ensure adequate longterm supplies of the earth's non-renewable resources. However, current consumption and waste generation statistics still indicate a wide scope for applying a range of conservation measures: more efficient use of energy and materials; decreased growth in demand; slowing of demographic expansion; development of new materials and manufacturing processes; and, recovery and recycling of more wastes and byproducts [2-4]. It is the purpose of this paper to outline the positive contribution that waste and byproduct utilization in construction makes to materials conservation within the framework of current Canadian practice, and to indicate potential trends.

The construction industry, as a major force in a developing country with long transportation distances and rapid urbanization, requires large per capita supplies of low unit cost industrial minerals (mainly aggregates) that are becoming depleted near some urban demand points, or alienated by sprawl [5]. Coupled with bulk material requirements, the demand for cementing agents (mainly asphalts and portland cements) and fuels that are becoming increasingly expensive remains firm. These materials and indirect energy considerations also involve a growing concern for environmental protection during all construction-related activity, particularly minerals extraction and thermal processes. At the same time, waste handling and disposal poses a severe problem given the current emphasis on improved plant conditions and environmental impact. For activities in urban areas, the total cost of disposal to approved sites ranges from about \$5. to \$15. per ton, a cost factor of concern as profit margins on primary products are under pressure. Further, local authorities are tending to limit the dumping of non-municipal wastes in landfill sites, and requiring major plants to develop their own disposal areas that must meet stringent environmental controls.

Given this background, waste and byproduct utilization is particularly attractive since it couples resource conservation with attenuation of disposal problems. While numerous research studies, demonstration projects and current applications have resulted in optimistic projections of the role of wastes and byproducts as materials,

\* See list of references at the end.

some caution is required in the Canadian context as there are several limiting factors to be faced: current economic conditions, agency conservatism, obsolete specifications and industry structures that often result in little demand for a waste or byproduct that shows potential; mineral wastes that could make the largest contribution to bulk material requirements are widely distributed and usually remote from demand points; and the inherent variability of many wastes and byproducts. It is considered that the impact of waste and byproduct utilization on growing bulk materials needs will continue to be small, and the significant contribution will be in terms of recoverable/replaceable energy and special applications. These concepts will be illustrated by outlining applications for pelletized blast furnace slag, surplus sulphur and steel slag.

General Situation in Canada

In comparison with most countries, Canadians couple a rather voracious appetite for industrial minerals as summarized in Table 1 with a high rate of solid waste generation, particularly mining related, as indicated by the comparative statistics in Table 2. The

TABLE 1  
INDUSTRIAL MINERAL COMMODITIES PRODUCED IN CANADA, 1976 [6]

DESCRIPTION	PRODUCTION metric tons x 10 <sup>3</sup>	VALUE Can \$ x 10 <sup>3</sup>
Cement	9,850	339,159
Lime	1,825	54,099
Sand and Gravel	247,660	320,800
Stone	87,180	209,600
Clay Products	—	92,110
Asbestos	1,549	445,523
Gypsum	5,663	22,906
<b>TOTAL</b>	<b>353,727</b>	<b>1,484,197</b>

TABLE 2  
COMPARATIVE STATISTICS - AGGREGATES USAGE AND SOLID WASTE GENERATION  
(Quantities in metric tons x 10<sup>6</sup>)

ITEM	CANADA	UNITED STATES	UNITED KINGDOM
Aggregates Usage (1975)	291	1,560	230
Solid Waste Generation (1970)			
Municipal	10	227	14
Industrial	10	100	30
Agricultural			
- from animals	136	1,360	—
- other sources	50	499	—
Mining and Quarrying	399	998	100
Population (latest census, x 10 <sup>6</sup> )	23	203	56
Area (km <sup>2</sup> x 10 <sup>3</sup> )	9,976	9,363	241
Construction spending (1975, Can \$ x 10 <sup>6</sup> )	27,248	—	—

annual generation of municipal, industrial, agricultural and mining and quarrying solid wastes is often in addition to the huge accumulations from past activities. (The CANMET contribution to the seminar by R.K. Collings [7] gives significant further data on mineral waste generation.) At first examination, the statistics in Tables 1 and 2 appear to provide an ideal combination for fostering massive waste and byproduct utilization schemes. However, the information summarized is also symptomatic of the major problem facing any Canadian plans to increase waste and byproduct utilization - large transportation distances for the mining wastes that predominate in our resource-exploitive waste stream. In simplistic terms, the problem is one of dispersal of non-renewable resources and wastes (they are not physically destroyed), so that collecting them for recycling and/or utilization is usually an insurmountable task.

Based on participation in a recently completed OECD study on waste and byproduct utilization in road construction [8], and a current RILEM study on all construction applications, general criteria can be developed for the overall evaluation of wastes and byproducts:

1. The quantity available at one location must be large enough to justify the development of handling, processing and transportation systems. (For bulk applications about 50,000 metric tons per year is required, but smaller quantities of special end-use materials are acceptable - cementing and stabilizing agents for instance);
2. Reasonable transportation distances are involved in terms of competing with conventional materials; and
3. Must not be potentially harmful during use or following incorporation (toxicity, solubility, radioactivity, etc.).

Using these general criteria, and considering technical feasibility, it is possible to develop groupings for the overall evaluation of wastes and byproducts [8,9]:

Class 1 - Wastes and byproducts of maximum potential. They possess the best properties either in their naturally occurring, processed or combined form, or have a record of satisfactory performance.

Class 2 - Wastes and byproducts requiring more extensive processing and/or where properties are not as adequate as those in Class 1.

Class 3 - Wastes and byproducts showing less promise than Classes 1 and 2, and recommended for use only in isolated situations.

Class 4 - Wastes and byproducts showing little promise as construction materials.

This evaluation procedure during the OECD study involving twelve countries

resulted in the class listings given in Table 3, with the wastes and

TABLE 3  
OVERALL EVALUATION OF WASTES AND BYPRODUCTS FOR UTILIZATION IN CONSTRUCTION  
(Class 4 Omitted)

CLASS 1	CLASS 2	CLASS 3
blast furnace slags (1)*	phosphate slag	gold tailings
fly ash (3)	copper slag (6)	copper tailings
sulphur (2)	cement kiln dust (8)†	lead-zinc tailings
steel slag (4)	quarry waste	coke breeze
boiler slag } (7)	mine refuse	foundry sand (12)
bottom ash	slate waste	ceramic and
nickel slag (6)	bark and sawdust (9)	refractory wastes
demolition wastes (5)	fluorspar tailings	resin
colliery spoil	tires and rubber (11)	lignin
oil shale residue	zinc slag	potassium salt
taconite tailings	lead slag	mine wastes
china clay sand	mixed ash	pyrite cinders
iron ore tailings (11)	incinerator residue	waste glass (10)
pyrolysis residue		waste plastics
		cellulosic

\* Indicates overall evaluation of twelve most important wastes and by-products in the Canadian context. Extension of OECD study.

† Omitted from OECD overall evaluation [8].

byproducts placed in order of merit for road construction in each class. Obviously, individual countries will have different evaluations based on factors such as availability and local experience, and the writer has indicated an order of merit in Table 3 for the leading twelve in all construction applications in the Canadian context.

#### Canadian Inventory

Using CANMET data, typical waste generation coefficients (waste produced per unit of finished product) and considerable detective work, it has been possible to compile the data and notes in Table 4 for the twelve materials of most interest in Table 3. While refinement of this information is considered desirable, it is the mutual exchange of information (quantities, characteristics, availability) between actual waste producers and potential users that leads to most applications in the world of coupled technical/economic decisions. In this regard, the Canadian Waste Materials Exchange to be launched shortly by Fisheries and Environment Canada, should foster such interaction.

TABLE 4

INVENTORY OF CANADIAN WASTES AND BYPRODUCTS OF MAJOR INTEREST  
AS CONSTRUCTION MATERIALS

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
blast furnace slags (air cooled and pelletized)	$2.2 \times 10^6$ metric tons/yr	air cooled - aggregate (base, PCC, AC)*, ballast, EF, mineral wool pelletized - lightweight aggregate (PCC, masonry), separately ground slag cement
		23% of 1975 pig iron production. Production fairly static. Pelletizing developing rapidly ( $\approx 0.2 \times 10^6$ metric tons in 1976), remainder air cooled. Hamilton (Southern Ontario) major production and utilization area. Use as aggregate covered by ASTM and CSA standards. CSA developing standard for separately ground slag cement. Research in progress: partially preground pelletized slag in autoclaved masonry production <sup>+</sup> ; and pelletized slag in base stabilization <sup>+</sup> . Most of available blast furnace slag utilized. Full utilization anticipated in near future.
sulphur	$\approx 16 \times 10^6$ metric tons surplus currently in storage	insulations <sup>+</sup> , AC, concretes, coatings <sup>+</sup>
		Sulphur Development Institute of Canada (SUDIC) estimate for end of 1975, projection of up to $25 \times 10^6$ metric tons by 1980. Only surplus byproduct sulphur is considered in context of this report, mainly from Alberta sour gas fields. Standards for various use not developed yet. Significant research and development in progress; insulation <sup>+</sup> (sulphur foam and thermal AC); AC (binder system, sulphur/asphalt emulsions and specialty applications); concrete (hot poured sulphur concrete, additive to PCC <sup>+</sup> and impregnating agent for PCC); and coatings <sup>+</sup> (mortarless construction, linings and soil stabilization). Little surplus sulphur now utilized in construction as mainly at developmental stages. More utilization should develop.
fly ash	$1.8 \times 10^6$ metric tons/yr	pozzolan in PCC, lightweight aggregate <sup>+</sup> , base stabilization <sup>+</sup> , EF
		CANMET production data. Production increasing rapidly, projection of up to $2.7 \times 10^6$ metric tons/year by 1980. Currently produced in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta. Uses generally covered by ASTM and CSA standards. Significant research and development in progress: portland-pozzolan cements; pozzolan specifications; and efficient lightweight aggregate production. Little fly ash now utilized ( $\approx 90,000$ metric tons/year), most goes to disposal sites and/or landfill projects. Fuller utilization anticipated as markets developed.

\* See notes at end of Table 4.

Continued ...../7

TABLE 4 (Cont'd)

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
steel slags	$1.3 \times 10^6$ metric tons/yr	aggregate in AC, ballast <sup>+</sup> , EF
		20% of 1975 steel ingot and casting production, less 50% recycle to blast furnace burden. Future production increases may be offset by increased recycling. Hamilton (Southern Ontario) major production and utilization area. Uses generally covered by local agency or owner specifications. (Since potentially expansive, care must be taken in EF.) Research in progress: skid resistance in AC; and pavement design for steel slag AC. Little steel slag now used outside of works ( $\approx 18,000$ metric tons/year in AC), in potential demand areas work's applications (EF) takes most. Much greater use in AC anticipated.
demolition wastes (including excavation spoil)	$30.4 \times 10^6$ metric tons/yr	building demolition - timber, lumber and bricks excavation spoil - EF old PCC - aggregate (base, PCC <sup>+</sup> , AC <sup>+</sup> ), EF old AC - aggregate (base, AC), EF
		Extension of Hamilton-Wentworth Region data, 1.32 metric tons/capita/ year for all demolition, excavation and construction wastes. Production increasing. Standards for various uses not explicitly developed, but often covered by ASTM and CSA standards for conventional materials. Significant research and development in progress: recycling old PCC as aggregate in PCC; and recycling AC. Except for much use of excavation spoil in EF, most demolition waste goes to disposal sites and/or landfill projects. Significant recycling of AC is anticipated.
nickel and copper slags	$\approx 1.9 \times 10^6$ metric tons/yr	aggregate in base construction, ballast, EF
		Estimated from CANMET data and 1975 nickel and copper production. Production variable, depends on world nickel and copper demand. Sudbury major nickel slag production, and base construction and EF utilization area. Ballast hauled up to 800 km from production points. Uses generally covered by local agency or owner specifications with some ASTM standards. Research in progress: cemented mine back-fill using a cementitious blend of ground vitreous non-ferrous slag (copper, nickel, lead, etc.) and PC. While ballast applications use a significant amount of current production, generally remote location of nickel and copper slags (and other non-ferrous slags) has resulted in considerable stocks in addition to much of current production. More utilization may develop.

Continued ...../8

TABLE 4 (Cont'd)

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
bottom ash	$\approx 0.45 \times 10^6$ metric tons/yr	aggregate <sup>+</sup> (base, AC), EF
Estimated from CANMET fly ash data, for power plants only. Production increasing rapidly. Currently produced in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta. Standards for various uses not developed yet, but some local agency, owner, ASTM and CSA specifications and standards applicable. Research in progress: applications in road construction; and influence of soluble sulphates. Except for small quantities used in demonstration projects and some EF, most bottom ash goes to disposal sites and/or landfill projects. Boiler slag, if separate from ash, is widely utilized. More utilization of bottom ash may develop.		
cement kiln dust	$\approx 0.45 \times 10^6$ metric tons/yr	filler <sup>+</sup> , EF
Estimated from typical waste cement kiln dust production in Ontario and 1975 PC production. While production currently fairly static, large future increases anticipated, particularly with trend to suspension preheater dry process plants (bypass dust). Production in all major urban areas. Use as filler and EF covered by local agency or owner specifications. Research in progress: filler in asphalt mixes; and pozzolanic properties. (Much effort on other applications - fertilizer, waste treatment, absorption of $SO_2$ , etc.) Except for relatively small quantities used in EF, most waste cement kiln dust goes to disposal sites and/or landfill projects. More utilization, perhaps even full, will develop as more applications are demonstrated in both construction and other applications.		
bark and sawdust	$\approx 50\%$ of log volume (20% bark, 20% sawdust, 60% chips)	bark - recycling (pulp, particle board, fibreboard, fluting medium) roads <sup>+</sup> (frost protection layer, lightweight fill, temporary con- struction, filter course)  sawdust and chips - recycling (pulp, particle board, fibreboard) roads (same as for bark, main application is lightweight fill)

For each log processed, about half the volume emerges as residues. However, amounts not recycled or burnt during steam raising (or direct disposal that is decreasing) is very small proportion. Available quantities decreasing as recycling and fuel potential recognized. Lightweight fill applications covered by local agency special provisions. No known major research or development in progress. Lightweight fill applications use a very small quantity of wood wastes, and it is anticipated that full utilization within wood industry will be reached.

TABLE 4 (Cont'd)

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
glass	$\approx 1.2 \times 10^6$ metric tons/yr	aggregate <sup>+</sup> (base, AC), terrazzo <sup>+</sup> , bricks <sup>+</sup> , foamed and ceramic construction materials <sup>+</sup> , light reflecting road markings
<p>Estimated at 10% of municipal refuse (also estimate, 1975). Does not include glass industry waste that is recycled directly. Production trends difficult to predict as much pressure for more returnable containers, coupled with trend towards resource recovery from municipal and industrial refuse. Currently, little waste glass of suitable quality available for use in construction materials, but glass from resource recovery operations that is not recycled may become available in next few years. Standards for various uses not developed yet, but subject of ASTM committee. No known major research or development in progress. (Significant research in past on AC containing waste glass.) Except for very small quantities collected or separated for demonstration projects, most waste glass goes to landfill sites as part of refuse or incinerator residues. Until resource recovery operations develop, little utilization anticipated and recycling will compete.</p>		
iron mine overburden, cobbings and tailings	$\approx 72 \times 10^6$ metric tons/yr	aggregate (base, PCC, AC) ballast, EF, filler <sup>+</sup> , roofing granules, brick manufacture <sup>+</sup>
<p>Estimated from typical CANMET data and 1975 iron ore production. Production fairly static. As with most mining and quarrying wastes, very large stockpiles have built up. Fourteen iron mines in operation, mainly remote areas of Ontario and Quebec. Uses generally covered by local agency or owner specifications with some CSA and ASTM standards. No known major research or development in progress. While use as aggregate in AC (traprock), ballast and roofing granules has involved fairly large quantities (particularly in Ontario), transportation costs limit wide utilization. More utilization may develop.</p>		
tires	$\approx 11 \times 10^6$ tires/yr	aggregate and/or binder component in AC <sup>+</sup> (roads and sport areas)
<p>Estimated from tire replacement data. Production increasing (also waste plastics and other rubber wastes), but applications to capitalize on heat values (fuels and/or process stream) and chemistry may develop to require available production. Production in all areas. Standards for various uses not developed yet except in cases where natural materials replaced. Significant research and development in progress: cryogenic processing; and utilization in AC (strain relieving layers, binder and aggregate). Except for small quantities used in demonstration projects, waste rubber not recycled goes to disposal sites. Increased utilization as construction materials not anticipated as recycling, fuel value and recoverable components will offer strong competition for supply.</p>		

Continued ...../10

TABLE 4 (Cont'd)

WASTE/BYPRODUCT	PRODUCTION	MAIN USES
foundry sand	not known, probably greater than $1 \times 10^6$ metric tons/yr	EF, PC manufacture <sup>+</sup> , pipe bedding, backfill

Production data not available, but quantity probably decreasing as recycling becomes norm. Southern Ontario and Montreal area major production and EF utilization areas. Uses generally covered by local experience with some agency or owner specifications. Significant research and development in progress: use as kiln feed in PC manufacture; and specifications for EF, bedding, backfill, etc. applications. At times, large quantities used in EF, but usually goes to disposal sites and/or landfill projects. More utilization should develop.

NOTES: PC - portland cement  
 PCC - portland cement concrete  
 AC - asphaltic concrete  
 EF - engineered fill  
 ASTM - American Society for Testing and Materials  
 CANMET - Canada Centre for Mineral and Energy Technology  
 CSA - Canadian Standards Association  
 + - potential use, technical feasibility demonstrated

For the wastes and byproducts listed in Table 4, only blast furnace slags currently find nearly full utilization in construction. Large quantities of the other waste materials are still available for application where they are technically feasible, and economically competitive with conventional materials when appropriate environmental enhancement factors are considered. The relatively low ranking for municipal wastes such as incinerator residue, tires and glass may seem surprising since these wastes are those commonly confronting the average citizen and the subject of much recycling and utilization research. However, the quantities are small compared to other wastes (Table 2), and the potential for comprehensive recycling of municipal refuse appears more favourable from the conservation, technical and economic viewpoint [10]. While Canada tends to be quite advanced in several areas (for instance, pelletized blast furnace slag, surplus sulphur, nickel and copper slags, and steel slags), many other countries are making far better use of materials such as fly ash, boiler and bottom slags, and a wide range of mining wastes. Fly ash is a key byproduct where developmental and marketing activities should foster a demand based on positive research and applications in many countries.

Even if the full materials and energy potential of each waste and byproduct listed in Table 3 is exploited along the lines suggested for the leading twelve in Table 4, it is clear that they can only make a small contribution to construction needs (perhaps 5% to 10% of bulk materials), given the generally remote location of most mining wastes. It is in the areas where these materials offer special advantages - cementitious applications for pelletized blast furnace slag, surplus sulphur as a binder in a number of construction applications, steel slag in skid resistant asphaltic concrete, fly ash as a pozzolanic addition to portland cement concrete and many others -

that much scope is still available to the materials engineer.

#### Recoverable/Replaceable Energy and Special Applications

In a paper of this nature, it is only possible to indicate trends in the present and potential uses of wastes and byproducts as construction materials. However, a few examples will be given to illustrate the important concept of taking full advantage of the energy and materials potential of wastes and byproducts.

#### Pelletized Blast Furnace Slag [11,12]

By selective cooling, three distinct types of iron blast furnace slag have been produced for many years: air-cooled, which finds extensive use in conventional aggregate applications; expanded, which is used mainly as a lightweight aggregate; and granulated, which is specifically produced in a noncrystalline state (vitreous) for the slag-cement industry. A relatively new process, developed by National Slag Limited in Hamilton involves direct pelletizing to produce a lightweight aggregate. Pelletized blast furnace slag is produced from the molten slag by expanding it under water sprays on a feed plate, and then passing this expanded pyroplastic material over a rotating finned drum where the fins on the drum break it up and "fling" the slag in the air for a sufficient time that surface tension forms pellets. These quenched slag pellets have a vesicular amorphous structure of varying degree which has latent cementitious properties, i.e. have a pelletized granulate. A number of benefits of pelletizing blast furnace slag have been demonstrated - gas emission control, time and space savings in slag handling, reduced cement requirements and increased workability for both masonry and structural type lightweight mixes, and cementitious applications - that have resulted in a number of installations throughout the world.

While aggregate applications are important, it is in the cementitious applications that slags will have their greatest impact on industrial minerals requirements. By grinding to cement fineness, pelletized slag provides a satisfactory substitute for a large portion of the portland cement in a concrete mix. The resultant energy saving is significant, since clinkering portland cement in a wet process plant requires about 6.5 MJ per kg. The success, and expansion plans of Standard Slag Cement Company in Hamilton have demonstrated the viability, both technical and economic, of such a separate grinding and cement replacement process.

Partial grinding of pelletized slag also offers a way that the cementitious properties can be utilized in a base stabilization process, and during the manufacture of autoclaved bricks and blocks. A stabilized base meeting typical specifications has been developed [11] using 30% partially preground pelletized slag (16% to 20% minus 75  $\mu\text{m}$ ) as the cementitious material. As an extension of this process, the use of partially ground pelletized slag as a combined cementitious material/aggregate in autoclaved block manufacture has been demonstrated during

plant trials for both heavyweight and lightweight blocks. This innovative procedure allows portland cement replacements of up to about 67%. Current research in the Construction Materials Laboratory at McMaster University is now focussed on the hydraulicity factors involved with such applications for pelletized slag. The substantial energy savings possible through the cementitious nature of vitreous slags should result in a growing demand as the Canadian construction business "picks up".

#### Surplus Sulphur [13]

The Canadian surplus sulphur problem has been the topic of much discussion and has resulted in significant research and development activities to develop new products to broaden the industrial and construction uses of sulphur on a sound economic basis, i.e. commercial viability must not depend upon distress sulphur prices. Much of this sulphur work is coordinated by the Sulphur Development Institute of Canada (SUDIC), which involves Federal, Alberta and sulphur industry support. It is clear that Canada is taking the leadership in developing the utilization of this byproduct sulphur currently associated with sour gas fields, but potentially resulting from environmental control of process emissions. Some of the major applications developed are: sand-asphalt-sulphur mixes; sulphur/asphalt binder; sulphur concretes; sulphur-impregnated concrete, blocks and bricks; sulphur mortars; sulphur for land stabilization; sulphur for pond and ditch linings; sulphur composites; and sulphur foams. It is likely that this list does not cover all potential applications and more are in the developmental stage.

#### Steel Slag [12]

In contrast to iron blast furnace slag which is fairly light and stable, steel slags (open hearth, basic oxygen furnace, electric arc, etc.) have a much higher bulk density and potentially expansive behaviour associated with their free lime content. However, with correct aging and evaluation procedures, uncoated steel slags can be used in a wide range of engineering applications. Research has shown that the use of steel slags in asphalt mixes (i.e. coated products) is a more logical step since potential expansion is readily controlled and an excellent product is produced [12]. Steel slag asphalt mixes combine a very high stability with good flow and excellent stripping resistance. Test sections, PSV tests and accident-skid resistance surveys indicate that steel slag asphalt mixes provide the required skid resistance for both highway and urban situations. It would appear that steel slag is the most skid resistant aggregate available in Southern Ontario, and its use on major provincial and municipal projects is becoming more common.

Steel slag is an excellent example of a byproduct (or a waste in too many cases) that has some economic disadvantages - high bulk density and potential expansion - that can be readily offset by demonstrated advantages - high stability and excellent skid resistance in asphaltic concrete mixes. Current steel slag research in the Construction Materials Laboratory at McMaster University involves both skid resistance optimization, and the incorporation of high stability mixes in rational pavement designs.

### Conclusion

There is still much potential for the utilization of wastes and byproducts as resources to be developed, and the inventories are certainly available. However, optimistic forecasts must be tempered with the harsh reality of both technical and economic constraints that will tend to limit applications to those where energy is recovered or saved, or the waste or byproduct offers performance advantages. An integrated approach by governmental, industrial and research organizations, taking into account the technical, economic, environmental and energy factors involved, is needed to foster the new technology required for waste and byproduct management and utilization.

While referring to municipal refuse in the United States, recent remarks by R.A. Petrone (President, National Center for Resource Recovery) give a clear picture of the current Canadian situation:

*"I am sure that future researchers will view the decade of the 1970's as a period when the recovery movement in this country was born and developed ... experienced assorted ills and growing pains ... reached stages of demonstration ... and had its beginnings of commercial application". [14]*

### Acknowledgement

The author wishes to thank all of the organizations that have supported the Construction Materials Laboratory, and the many colleagues involved.

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## INDUSTRIAL WASTE MATERIALS EXCHANGES

Presentation to the Seminar

"UTILIZATION OF MINING AND INDUSTRIAL WASTES"

Sponsored by

Ontario Ministry of Industry and Tourism  
Toronto

October 13, 1977

by

R. G. W. Laughlin

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#### INDUSTRIAL WASTE MATERIALS EXCHANGES

The concept of the waste exchange is predicated on the old adage that "one man's meat is another man's poison" or, as it may be restated today, "one man's garbage is another man's gold". Waste industrial material, as we have been considering today, may well prove to be a useful feedstock for another company. In order that companies may consider using a waste material they must first know of its existence. This information transfer is achieved by a Waste Materials Exchange which has been described as "an industrial flea market" or "an industrial bargain hunter's press". The objectives for such an exchange are shown in Slide 1.

Large companies with many processes and skilled technical staff are likely to find numerous recycling opportunities within their own manufacturing facilities. However, even technical people in large national companies are not likely to recognize all waste transfer opportunities outside of their own industry. Thus the concept of spreading the word about the availability of particular wastes is attractive in that it increases the number of people examining possible uses for the wastes. Wastes are likely to move from large companies to smaller ones.

There are a total of 17 Waste Materials Exchanges of the information exchange only type in Europe and North America, and all of them were contacted by ORF during the course of our study. Other operations, such as chemical brokers and waste reprocessors have called their operations waste exchanges. However, a distinction was drawn between these "active" exchanges and the type of "passive" information transfer only exchanges in which we were interested. Waste materials pass through an active exchange physically, economically and legally. The responsibility for the wastes' characteristics, as far as the user is concerned, lies with the waste exchange. For an information only exchange, no legal responsibility rests with the exchange; the transaction is between the generator and the user of the waste, the exchange only having served to introduce the two parties.

In the next slides, 3 - 7, the 17 waste exchanges in existence are listed in 5 groupings depending on the operator and sponsor of the exchange. Of these 17, the most successful seem to be the Deutscher Industrie und Handelstag (DIHT), U.K. and Nordic Waste Exchanges. The DIHT exchange has the advantage of a distribution list for its exchange information of some 700,000 companies, as it is a legal requirement in Germany for all companies to belong to the Chamber of Industry and Commerce.

All of the exchanges have only been operating for a relatively short time, the oldest being the Dutch exchange which started in January, 1972. Most include two sections in their exchange literature - an Available and a Wanted section - so that companies looking for substitute raw materials can also list with the exchange. Because some of the compositions of waste streams to be listed on the exchange could be either embarrassing to the lister or could indicate what process he is using to his competitors, all but two of the exchanges list entries anonymously. Enquiries are sent to the exchange which passes them on to the lister who can decide whether the enquiry is bona-fide or not before he makes contact with the enquirer.

In assessing the success of the various exchanges, we considered several factors which are shown in slide 8.

Costs of Exchange operation are not well defined except in the case of the U.K. where a government grant of £70,000 (\$112,000) was made for a two year trial period. During that period, about 125 items were known to have exchanged and these were calculated to have replaced £5 million (\$8 million) worth of virgin raw materials.

Slides 9 and 10 show the front cover of a recent U.K. Waste Exchange bulletin, and a portion of the listings from that issue. This illustrates the code numbers used to identify wastes, so that the actual generator can remain anonymous. The last letter in the reference code indicates where in the U.K. the waste is available. Quantities are either given in amount per unit time or as a batch quantity available once only.

In slides 11 and 12 some indication is given of the success of the Nordic and U.K. exchanges in placing transferring wastes. These tables break down the wastes by material types. As can be seen, success rates are quite different for different materials. Acids are particularly hard to find uses for. This detailed analysis was carried out quite early in the life of the U.K. exchange. Since then the overall transfer rate has risen from 11.6% of the wastes listed to 18% of wastes listed transferring.

During the study we contacted many people in Industry in Canada and also in the secondary materials industry. All of them seemed to be very enthusiastic about the waste materials exchange concept. Based on this response and our findings in studying existing exchanges, we recommended that a national Canadian Waste Materials Exchange be established. While we recognize that wastes will probably not transfer from St. John's to Vancouver, a national exchange which deals only in information should minimize administrative costs and maximize the number of people it can reach. Exchanges are likely to take place over fairly short distances because of the inherently low values for waste materials. Slide 13 shows the characteristics we have recommended for the Canadian Waste Exchange.

The Waste Management Branch of Fisheries and Environment Canada have accepted our recommendations and intend to sponsor a national waste exchange for a two-year trial period, after which the exchange, if successful, should become self-supporting. The Waste Management Branch in conjunction with Department of Supply and Services has solicited expressions of interest in operating the exchange from a number of proponents and will soon be awarding a contract to commence operations. It is anticipated that the exchange will be in operation by November 1, 1977. Bulletins will be issued every two months. Slide 14 shows a suggested front cover of Bulletin No. 1.

If anyone is interested in being included on the mailing list for the Canadian Waste Materials Exchange, please contact me at Ontario Research (416) 822-4111.

The objectives for such an exchange are:

1. To save valuable raw materials;
2. To save energy by not having to process raw materials;
3. To avoid environmental damage:
  - (a) in the winning of raw materials and energy
  - (b) in the avoidance of having to dispose of the waste.

- From larger companies using continuous processes to smaller companies using batch processes;
- From basic chemical manufacturers to formulators;
- From industries with extremely high purity requirements (e.g. pharmaceuticals) to those with lower purity requirements (e.g. paints).

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1. Those Operated by Industrial Societies for their Membership

Verband der Chemischen Industrie (VCI), West Germany

Schweizerische Gesellschaft für Chemische Industrie  
(SGCI), Switzerland

Ecochem Bourse, Belgium

Vereniging van de Nederlandse Chemische Industrie  
(VNCI), Holland

Associazione Nazionale dell Industria Chimica  
(ANIC), Italy

National Industrial Materials Recovery Association  
(NIMRA), U.K.

2. Those Operated by Organizations such as Chambers of Commerce

Deutscher Industrie-und Handelstag (DIHT), West Germany

Handelskammer der Ober Österreich (HKÖÖ), Austria

St. Louis Regional Commerce and Growth Association,  
U.S.A.

Iowa Industrial Waste Information Exchange, U.S.A.

Houston Chemical Recycle Information, U.S.A.

3. Those Operated by Commercial Magazines

Nuisances et Environnement, France

Canadian Chemical Processing, Canada

4. Those Operated by Government

Ontario Ministry of Industry and Tourism, Canada

Tennessee Dept. of Public Health, U.S.A.

5. Those Sponsored by Government, Operated by Independent Labs

U.K. Waste Exchange, U.K.

Nordic Exchange, Scandinavia

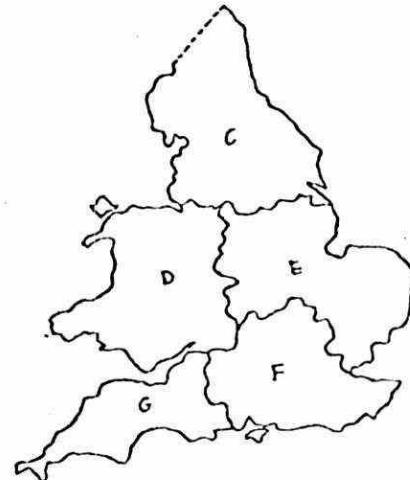
- Circulation of information: ranged from 600 - 700,000
- Listings per year: ranged from 5 - 5,000
- Enquiries per listing: ranged from 0.5 - 5.25
- Proportion of wastes listed & actually exchanged: ranged from 10% - 50%



11

On the map the country has been divided into the seven geographical regions listed. In the Bulletin listing the area letter has been added to the end of the reference. Thus AA112E is an available item in area E. Also note that new items come after the dotted line.

- A Scotland
- B Northern Ireland
- C North of England
- D West Midlands and Wales
- E East Midlands and East Anglia
- F Central Southern and South East England
- G West of England



There are two forms at the back of the Bulletin:

Contact Request Form

To be used for notifying an interest in obtaining the available materials listed.

Notification Form

To be used for notifying available items for inclusion in the next issue of the Bulletin. It should however be realised that scrap metals, second hand equipment and related materials for which adequate commercial markets already exist are not accepted for entry in the bulletin.

Please note that contact is made by sending the name of the person who wants the waste to the company who advertised it in the bulletin. The identity of the company wherein the arising occurs is never disclosed by the Exchange, and commercial arrangements are made directly between the companies, not through the Exchange.

UK Waste Materials Exchange, PO Box 51, Stevenage, Herts SG1 2DT.  
Telephone: Stevenage (0438) 3388

SECTION A: MATERIALS AVAILABLE

REF R	QUANTITY	ACIDS & ALKALIS
AA030C	200000 GL/H	10-12% CAUSTIC SODA WITH 4% SILICA
AA039F	25000 TN/Y	18% SULPHURIC ACID WITH 48% AMMONIUM SULPHATE
AA040G	25 TN/H	SULPHURIC ACID TAR FROM HYDROCARBON OIL REFINING
AA110F	10 TE/H	60% SULPHURIC ACID, 5% HYDROCHLORIC ACID, NO ORGANIC CONTH
AA209D	1500 GL/D	14% AQUEOUS AMMONIA WITH 7% METHANOL
AA268F	15000 GL/D	KIER LIQUOR, 3% CAUSTIC SODA PLUS SODA ASH
AA270F	3 TN/D	CALCIUM HYDROXIDE/CARBONATE CAKE, 55% MOISTURE, 5% NITROGN
AA278F	4 TN/M	CAUSTIC SODA SLAG (LUMPS) CONTAINING ZINC
AA307F	500 GL/W	10% CAUSTIC LIQUOR, 20% ORGANIC CHEMICALS, 10% SOLVENTS
AA461F	3000 GL/H	WASTE ACID, 5% SULPHURIC, 3% HYDROCHLORIC, 1% NITRIC
AA644C	40000 GL/W	45% SULPHURIC ACID WITH 3% NITRIC ACID
AA655F	3000 GL/M	10 % AQUEOUS SOLUTION AMMONIA
AA682C	12 TN/Y	PHOSPHOROUS ACID WITH SOME ORGANICS & CHLORIDE
AA716D	15000 GL/H	4/10% SULPHURIC ACID WITH IRON SULPHATES
AA747F	40000 GL/H	15% SULPHURIC ACID, CLEAN, CONTAINS 0.2% CHLORIDE
AA814D	30 TE/Y	50% ACETIC ACID CONTG TRACES PHOSPHORIC ACID
AA888D	30 TE/W	SULPHURIC ACID 80% H/W CONTN'S SMALL AMTS POLYSULPHONATES
AB091C	1500 TN/M	30% SULPHURIC ACID, 45% AMMONIUM SULPHATE SOLUTION
AB172F	60000 GL/W	4% HYDROCHLORIC ACID - SMALL AMOUNT METALS
AB382D	1000 LT	CONC HCL IN CARBOYS
AB405F	15 TE/M	PHOSPHOROUS ACID, 50% AQUEOUS EX ACID CHLORINATION
AB410C	3000 GL/M	10% CAUSTIC SODA, 10% POLYSULPHIDES, 10-20% NA ALUMINATE
AB412C	1000 GL/M	10% NITRIC, 10% HYDROFLUORIC, 5% SULPHURIC ACIDS +NI, CR, FE
AB413C	1000 GL/M	5% SULPHURIC, 2% CHROMIC ACID PLUS UP TO 2% ALUMINIUM
AB429D	12000 GL/H	15% W/H SULPHURIC ACID CONTAINING 1.2% ALUMINIUM
AB471E	1000 GL/M	SULPHURIC ACID 25%/ISOPROPANOL 75%
AB543F	14 TE/H	40% SULPHURIC ACID - SUITABLE FOR EFFLUENT TREATMENT
AB544F	4 TE/M	30% HYDROCHLORIC ACID
AB587D	1500 GL/W	12.5% SULPHURIC ACID WITH 15 G/L ALUMINIUM SULPHATE
AB588D	3500 GL/H	AMMONIA SOLUTION - 10%
AB600D	5000 GL/M	5 - 10% CAUSTIC SODA WITH 10 - 15% ALUMINIUM
AB671D	12480 KG	CAUSTIC SODA - SOLID U SHAPED
AB676A	7000 GL/D	3-5% CAUSTIC SODA SOLUTION CONTAINING 0.5% SULPHIDE
AB682D	10000 GL/H	4% CAUSTIC SODA, SETTLED MERCERISER WASTE
AB707C	11 TE/U	55% SULPHURIC ACID, DARK BROWN & SOME CHARRED ORGANICS

REF R	QUANTITY	CATALYSTS
AA024C	25 TE/Y	SPENT CATALYST, 4-5% VANADIUM PENTOXIDE
AA173F	100 TE	NICKEL CATALYST 3-5% NICKEL
AA505E	30 TH/M	SPENT CATALYST, MAINLY PARTICULATE ALUMINIUM SILICATE
AA507C	17 TE	ZINC ACETATE CATALYST (UNUSED) APPROX 68% NORITY CARBON
AA538F	300 TN	NI&CO-MO HYDRODESULPHURIZING CATALYSTS, NEW OR RE-USABLE
AA539F	200 TN	NEW, RE-USABLE, SCRAP STEAM-REFORMING CATALYST 4-17% NI
AA540F	150 TN	RE-USABLE WATER GAS SHIFT CATALYST, CHROMIA-IRON OXIDE
AA702C	4183 KG/Y	NICKEL/ALUMINIUM ALLOY FOR CATALYST
AA703C	335 KG/Y	RAHEY NICKEL CATALYST
AA704C	200 KG/Y	NICKEL CATALYST
AB042D	50 TH	PELLETISED CATALYST, 5% VANADIUM PENTOXIDE IN SILICA BAS
AD320A	80 GL	PALLADIUM BEARING PLATING ON PLASTIC CATALYST (USED)
AD415C	25 TN/W	SPENT ZINC CATALYST SOLUTION, 3% ZINC, 7% IRON
AB750D	20 TE	WET ALUMINA CATALYST - 5% CU, 0.5% K AS CHLORIDES

TABLE 2 - Nordic Exchange  
Summary of Two Years of Operation 1973-1975

<u>Waste Category</u>	<u>Percent of Total Listed (%)</u>	<u>Enquiries per Item</u>	<u>Positive Results per Item</u>
1. Plastics	23.7	2.5	0.2
2. Textiles	12.6	4.1	0.4
3. Paper	5.2	2.4	0.4
4. Solvents	6.7	1.2	0.4
5. Acids	7.4	0.2	0
6. Inorganic Chemicals	11.5	1.5	0.5
7. Organic Chemicals	7.8	0.7	0.3
8. Slags, sludges	7.0	2.2	0.2
9. Miscellaneous	18.1	1.0	0.1
	<hr/> 100.0		

Category	Items Listed	Number Subject to Enquiry	Number of Enquiries per Listing	Number of Transactions
1. Acids & Alkalies	44	36 (82)	8.5	7 (16)
2. Catalysts	21	20 (95)	3.9	2 ( 9.5)
3. Inorganic Chemicals	127	106 (83)	3.4	17 (13.4)
4. Organic Chemicals & Solvents	190	154 (81)	5.7	32 (16.8)
5. Food Processing	18	18 (100)	14.5	6 (33.3)
6. Metals	64	49 (76)	3.6	3 ( 4.7)
7. Minerals	98	82 (84)	5.1	6 ( 6.1)
8. Miscellaneous	99	82 (83)	5.1	13 (13.1)
9. Oils and Waxes	49	43 (88)	5.8	9 (18.4)
10. Paper and Board	64	62 (97)	7.2	5 ( 7.8)
11. Rubber and Plastics	194	130 (67)	4.9	24 (12.4)
12. Textiles and Leather	109	93 (85)	5.9	1 ( 0.9)
	1,077	884 (82%)	5.4	125 (11.60%)

U.K. WASTE EXCHANGE

- One Exchange Should Serve All of Canada
- It Should Be An Information-Only Exchange
- It Should Cover All Industries
- Participation Should Be Free During A 2-Year Trial Period
- Sponsorship During The Trial Period Should Be By The Federal Government
- The Exchange Should Issue Its Own Bulletin
- The Bulletin Should Issue 6 Times Per Year
- The Bulletin Should Have 3 Sections
- Wastes Should Be Listed In Successive Bulletins
- Data Storage And Handling Should Be Mechanical
- Exchange Operators Should Actively Promote The Waste Exchange Concept
- Exchange Operator Should Offer Technical Help On Waste Reuse
- The Exchange Should Not Be Involved In Negotiations Between Lister and Enquirer
- The Exchange Operator Should Recommend Areas For R and D
- The Exchange Operator Should Evaluate The Exchange



The letters of this map are used to identify the geographic region in which waste materials are available or wanted. The letter appears as the last letter in the waste code number.

Wastes are listed in the bulletin under 10 categories:

1. Organic Chemicals and Solvents
2. Oils, Fats and Waxes
3. Acids and Alkalies
4. Other Inorganic Chemicals
5. Spent Catalysts
6. Metals and Metal Containing Sludges
7. Plastics
8. Textiles, Leather and Rubber
9. Wood and Paper Products
10. Miscellaneous

Listings will appear in the language submitted

Les lettres inscrites sur cette carte indiquent la région géographique où des déchets sont disponibles ou demandés. Cette lettre devient le dernier caractère du code de déchet.

Les déchets sont inscrits au bulletin sous 10 catégories:

1. Produits chimiques organiques et solvants
2. Huiles, graisses et cires
3. Acides et alcalis
4. Autres produits chimiques inorganiques
5. Catalyseurs vieillis
6. Métaux et boues contenant des métaux
7. Plastiques
8. Textiles, cuir et caoutchouc
9. Produits en papier et bois
10. Divers

Les inscriptions paraîtront dans la langue de leur soumission

# Industry urged to utilize more waste materials

By ALF BIRD

TORONTO (DCN) — Better utilization of waste materials requires more interest on the part of industry and government, says R. K. Collings, of the federal department of energy, mines and resources.

Collings, addressing a one-day seminar last week on mining and industrial waste, urged industry to make proposals to government for waste utilization research programs because there was

money set aside for this work. Collings is head of the department's minerals section.

Approximately 200 executives from mining, primary industry and construction attended the seminar which was sponsored by the Ontario ministry of industry and tourism, the Ontario ministry of the environment and Environment Canada as well as Collings' department.

Much of the present use of waste materials occurs in the construction industry for roads, concrete, aggregate, brick and blocks, and other products, said Collings.

He said much more waste material could be utilized but that the maximum probably would be only 10 per cent of the approximately 400-million tons produced annually in Canada alone.

## TOO FAR AWAY

"The bulk of it will never be used because it is too far away from its market," he said.

As an example, he said at present only about 100 tons per year of fly ash is used whereas approximately two-million tons are produced annually in Canada.

Currently, about one-half million tons of blast furnace slag is consumed annually in road base, lightweight aggregate and mineral wool, said Collings.

Two-million tons per year of steel slag is utilized in highway base and shoulder construction, fill, and as

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## • Industry

Continued from Page B1

aggregate in bituminous mixes, he said.

John Emery, department of civil engineering, McMaster University, Hamilton, said it appeared Canada leads in several utilization areas such as pelletized blast furnace slag, surplus sulphur, nickel and copper slags, bark and sawdust, and is particularly strong in slag utilization research.

### MAKE BETTER USE

However, many European countries are making far better use of materials such as fly ash, boiler and bottom slags and a wide range of mining wastes, he said.

"Canada is a very wasteful country," he said. "We are the biggest per capita producer of waste."

Materials with the most potential for use in highway construction are blast-furnace slag, sulphur, fly ash, steel slag and demolition wastes, in that order, he said.

"Our record of waste utilization is pretty miserable," he said.

However, much of this is due to the limits imposed by the long transportation distances involved in marketing potential products, he said.

*Daily Commercial News, October 19, 1977*

## Firm assists in use of wastes

TORONTO (DCN) — A Canadian consulting engineer says it is more difficult to find waste utilization projects in this country than in many other parts of the world.

Herb Bergstrom, president of H. Bergstrom International Ltd., Toronto, told a seminar on the utilization of mining and industrial waste that "old world countries" are much more aware of the importance of waste utilization and conservation.

"Most of our clients in this developing and challenging field are outside Canada," he said.

To try to overcome the disinterest in this country,

See FIRM, Page B3

### • Firm

**Continued from Page B1**

Bergstrom said, his firm had tried a new approach and was offering to analyse the waste materials of some potential clients at no cost to them.

#### PROVIDE SOLUTION

"At times, we can come up with a solution for their use, the processing system and a potential market or customer," he said.

In one instance, he said, his consulting firm had spent 2½ years studying the waste material of one client before a proposal could be made. There was no remuneration during that time, he said.

Currently, the consulting firm is involved in seven different waste projects, said Bergstrom.

He said Canadian industry should adopt the philosophy of many European firms that the target should be utilization of 100 per cent of the raw material employed in making a product.

*Daily Commercial News, October 19, 1977*

# Use of slag, fly ash said to grow

By ALF BIRD

**TORONTO (DCN)** — Utilization of slag (a mineral processing byproduct) and fly ash (a coal furnace byproduct) will show better growth in the future, a one-day seminar on waste utilization was told last week.

Don Lewis, chief engineer for the National Slag Association (U.S.) said: "We expect to see more and more slag used in lightweight aggregate."

He said it requires less energy in its production than competitive products and the lightweight cement provides better insulation in a structure.

He said slag and other such products should be identified as "recovered resources" rather than waste materials.

Lewis said the use of slags in construction is an old one, going back to the Romans who used it to build roads in Rome and Britain.

#### SLAG PROCESSED

In the United States, slag generally is processed and sold by independent companies who buy it molten from the steel companies, he said. A few steel companies are doing their own processing and marketing of the material.

Lightweight concrete made with slag aggregate requires a little more care in pumping as does concrete made with expanded shale aggregate, he said.

John Minnick of I. U. Conversion Systems Inc. said that despite numerous problems, progress in the utilization of fly ash is substantial in the U.S.

He said plants had been developed recently to premix fly ash ("which used to be called plain soot") and other material for road base, providing quality control of the product.

There's also been a lot of research into the contents and reactions of fly ash in a cement-type mix, he said.

#### STOOD UP WELL

Minnick said hundreds of miles of roads have been built using fly ash in recent years and have stood up well.

Another encouraging development, he said, was the pre-preparation plants for mixing lime, fly ash and additives to produce a new cement suitable for road sub-base, base and embankments.

Sludge is being combined with fly ash to produce a construction product for embankments, and structural landfill that can support roads and buildings, he said.

"Specifications are available for fly ash in various products," he said. "Attitudes (to waste utilization) are changing in the face of the energy shortage."

Only about 33 per cent of available fly ash is being utilized and the remainder is sluiced into a dumping pond. Of the portion that is utilized, 30 per cent goes into road construction and 16 per cent

is used as a partial replacement for cement, he said.

Reliability of supply and the fluctuations in the marketplace have been the main stumbling blocks to date, he said.

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